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ITSC RADTRAD Version 3.03

Verification and Validation Plan

ITSC/RUG-01-01 Revision 0

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1.0 BACKGROUND

The US Nuclear Regulatory Commission's (NRC) reactor site criteria, 10 CFR Part 100, requires that a fission product release into containment be postulated and that offsite radiological consequences be evaluated against the guideline dose values given in Part 100. Other NRC regulations, in 10 CFR Part 50, GDC 19, address regulatory requirements on the accident radiological doses for the control room. The evaluation of the release of fission products into containment (called "source term") is used for judging the acceptability of both the plant site and the effectiveness of engineered safety features. The U.S. Atomic Energy Commission published the original source term, which was based on releases from a severely damaged core, in 1962 (DiNunno 1962). This source term is referred to herein as the TID. Since that time there have been significant advances in our understanding of the timing, magnitude and chemical forms of the fission product release from severe reactor accidents. In February 1995 the U.S Nuclear Regulatory Commission published NUREG-1465 (Soffer 1995) that reflects extensive research and experience culminating in the development of a new or revised source term. This revised source term is referred to herein as the AST. The development of the revised source term was originally intended for initial application to advanced reactors though it was recognized that current reactors might want to utilize the revised source term in licensing actions. The impetus for operating reactors to adopt the revised source term is that through its more realistic characterization of the source term, plants may modify existing restrictive plant features, (e.g., component actuation times, leakage control systems).

In order to more fully evaluate issues associated with implementation of the revised source term at operating reactors, including assessment of the impact of revised dose acceptance criteria, the RADTRAD computer program was developed at Sandia National Laboratories. The RADTRAD program was designed to provide a simplified model for Radionuclide Transport and Removal and Dose Estimation that could be used as an analysis tool capable of estimating both on-site and off-site doses.

Sandia National Laboratories (SNL) previously documented the development, and validation of RADTRAD Version 2.20 (v2.20) in NUREG/CR-6604 (Humphreys 1998). SNL subsequently modified the numerical algorithm and the Graphical User Interface (GUI) to generate RADTRAD Version 3.01 (v3.01). RADTRAD v3.01 is described, and its validation documented, in Supplement 1 to NUREG/CR-6604 (Bixler 1999).

After initial testing, the RADTRAD program was used as part of the rebaselining project (Callan 1998) where the major design basis accidents were evaluated for several nuclear facilities. These evaluations used the traditional methods for the TID based scenarios and a consistent set of methods for the AST based scenarios. The results from these analyses were then used as part of the guidance for the revision of Chapter 15 of the Standard

Review Plan (NUREG-0800). This revision has been released as NRC Regulatory Guide 1.183 (NRC 2000).

2.0 INTRODUCTION

Innovative Technology Solutions Corp. (ITSC) has developed ITSC RADTRAD Version 3.03, hereinafter referred to as RADTRAD v3.03, starting from a previously released version, RADTRAD v3.01. RADTRAD v3.03 has been created through four primary categories of revision. They are:

- ***Category 1*** - Modifications to the Graphic User Interface (GUI) to provide a more useable program interface and to provide more complete input error checking to assure program limitations are not exceeded
- ***Category 2*** - Modifications to correct logic errors that existed in the previous version
- ***Category 3*** - Modification to the definition of a control room
- ***Category 4*** - Modifications to allow additional user editing of input/output

The specific revisions to the program in each of the categories are described in more detail in Section 3.0. These revisions are enhancements to the program. No significant changes to the fundamental program requirements or design have been made. RADTRAD v3.03 has also maintained the program revisions incorporated in RADTRAD v3.02. RADTRAD v3.02 has not been identified above as the source program for creation of RADTRAD v3.03 however, since it did not undergo program verification or validation. This Verification and Validation Plan also addresses the RADTRAD v3.02 program revisions.

This document provides the detailed plan for verification and validation (V&V) of RADTRAD v3.03. The V&V will be consistent with the ANSI/ANS guidelines for V&V of existing programs (ANS 1987, sec. 11). This type of V&V is appropriate since there is a current user base for earlier program versions, program documentation for earlier versions currently exists (including documentation of previous validation exercises) and as discussed above, the program revisions to create RADTRAD v3.03 are primarily enhancements (i.e., fundamental mathematical models and solution algorithms have not been significantly affected).

The primary objectives of the V&V of RADTRAD v3.03 are threefold:

- ***Objective 1*** - Validate the performance of the program revisions incorporated in RADTRAD v3.03
- ***Objective 2*** - Benchmark RADTRAD v3.03 against earlier validated RADTRAD versions and other industry recognized computer programs appropriate for this class of analysis

- ***Objective 3*** - Design review RADTRAD v3.03 to assess its adequacy for performing both on-site and off-site dose calculations that are consistent with current Regulatory requirements for evaluating design basis accidents. Specifically, problems have been developed to test the program for each accident scenario addressed by NRC Regulatory Guide 1.183 (NRC 2000).

There are two elements to the V&V of RADTRAD v3.03. The first element is program verification and will be implemented through design review of program requirements: first to assess the program as designed and second to assess the program requirements and their conformance with NRC requirements (NRC 2000). The second element is the program validation and will be implemented primarily through program testing. Details of the plan for both verification and validation are provided in Section 4.0.

3.0 DESCRIPTION OF REVISIONS INCORPRATED IN RADTRAD V3.03

As discussed in Section 2.0, there are four categories of revisions that have been incorporated in RADTRAD v3.03. This V&V plan will assure the performance of these revisions. Each of the substantive revisions is described, by category, below. RADTRAD v3.02 revisions that have been incorporated into RADTRAD v3.03 are noted.

Category 2 revisions are program modifications to correct logic errors. Numerical Applications, Inc. (NAI) previously identified (George 2000) some of the errors corrected in RADTRAD v3.03. Modifications to the program to correct these errors are noted as NAI-X, where X is a numeric identifier from the reference letter. The users of the program have previously identified the other errors listed under Category 2. Each of the identified errors was evaluated to determine its significance prior to developing the method of correction. A brief remark summarizing the error's significance is provided in each Category 2 revision description.

- ***Category 1 - Modifications to the Graphic User Interface (GUI)***
  - Allow the user to more easily remove a compartment, pathway, or dose location
  - Allow user to select pathway transport model and get default (no decontamination) values
  - Allow user to see the valid input range for the Powers' Spray model
  - Fixed maximum dose locations to 5
  - Corrected units for Henry correlation and Power's spray correlation (RADTRAD v3.02)
  - Default directory system linked to location of executable (RADTRAD v3.02)
  - Power's spray correlation fully linked to GUI (RADTRAD v3.02)
  - Multiple models allowed in a single calculation (e.g., sprays, natural deposition, recirculating filters, etc) (RADTRAD v3.02)

- Decay and daughtering available through GUI (RADTRAD v3.02)
- Iodine chemical for linked to inventory defaults (RADTRAD v3.02)
- Required saving of input data before calculation allowed (RADTRAD v3.02)
- Modified default edits (RADTRAD v3.02)
- Delay time activated from GUI (RADTRAD v3.02)

- ***Category 2 - Modifications to correct logic***
  - Multiple release paths from a compartment to the environment caused a significant conservative error in the control room dose, it became proportional to the number of paths
  - Control room filter deposition used incorrect array (< 0.1% effect on calculated dose)
  - Invalid filter loading values for all cases (no effect on calculated dose)
  - Suppression pool decontamination used incorrect volume (NAI-11) (< 0.1% effect on calculated dose)
  - A coefficient for the Gormley & Kennedy turbulent deposition model was in error (no effect on calculated dose)
  - Natural deposition model for APWR had a coefficient error (NAI-12) (no effect on calculated dose)
  - Powers natural deposition model used a derived removal coefficient instead of the current value (< 0.1% effect on calculated dose)
  - Dose conversion filename length could cause the code to terminate (no effect on calculated dose)
  - RADTRAD control of time steps to improve dose accuracy (RADTRAD v3.02) (< 1% effect on calculated dose)
  - Suppression pool decontamination that removed noble gases was corrected to allow their passage through the pool. (RADTRAD v3.02) (potential significant non-conservative effect on calculated dose)

- ***Category 3 - Modification to the definition of a control room.***
  - This modification was essentially a change to the definition of a control room. The control room was defined to be a compartment not included in the mass balance. This allows the offsite dose to be independent of the existence of a control room. Previously, the offsite dose would change (<1%) when a control room with a significant through flow was added. (NAI-7)
  - NRC Acceptance Test Case 16 (Table 8-1) originally called the auxiliary building a control room. As the mass balance excludes the control room, the input for this case was modified to allow a correct offsite and control room dose calculation. Doses can still be calculated in the auxiliary room by using an effective inlet χ/Q and an iodine protection factor formulation as was done in the rebaselining (Callan 1998) or by executing the model twice, first with the control room modeled as the control room and second with the auxiliary building modeled as the control room. This is the same procedure one would use to evaluate dose on the Technical Support Center.

- ***Category 4 - Modifications to allow additional editing of input/output***
  - Edit correct decontamination factors for the piping and Brockmann models
  - Edit the release fraction and timing file & the nuclide inventory file
  - Edit the dose conversion factor file (whole body, thyroid, and effective inhalation)
  - Edit the compartment type
  - Edit corrected group transport values when daughtering selected
  - Edit only the EAB 2 hour dose
  - Defined edited decontamination factor to be $(N_{atmosphere}+N_{deposited})/N_{atmosphere}$
  - Eliminated Overlying Pools as compartment decontamination
  - Added DE I-131 (ci/cc) to the compartment full edit
  - Added total transport through the path as well as deposition in the path to the full edit
  - Source initialization in multiple compartments (RADTRAD v3.02)

4.0 V&V APPROACH

The V&V of RADTRAD v3.03 will address six key areas. They are:

- Program requirements
- Program design
- Source code, program integration and documentation
- Program testing
- Test results-validation
- V&V review report

Many of these areas have been previously addressed and are documented in the validation of earlier versions of the program (Humphreys 1998; Bixler 1999). Therefore, the required extent of review for each of these areas will vary. The specific elements that will be reviewed in detail are described in the following sections.

4.1 Program Requirements

As discussed in Section 1.0, earlier versions of the RADTRAD program have been documented (Humphreys 1998; Bixler 1999). These documents are a principal source for the program requirements. This V&V will primarily review the mathematical models and solution algorithms used by the program for the purpose of determining any known limitations to the models and the class of problems that they best represent (i.e., the range of program responses that may be considered valid).

To fulfill Objective 3 of the V&V plan a detailed design review of RADTRAD v3.03 will be performed to evaluate program requirements and their conformance to NRC Regulatory Guide 1.183 (NRC 2000) requirements. The specific areas that will be reviewed and documented are summarized in Sections 4.1.1 through 4.1.3.

A primary focus of this V&V is on the use of RADTRAD v3.03 to analyze the most commonly controlling design basis accidents and to provide a technically defensible on-site and off-site dose calculation basis. To successfully meet Objective 3 of this V&V, RADTRAD v3.03 must comply with the NRC mandatory general requirements for accident source term and dose calculation methodology as well as any accident specific assumptions (NRC 2000).

4.1.1 Accident Source Term Requirements

NRC Regulatory Guide 1.183 (NRC 2000) provides specific requirements for an acceptable accident source term. These requirements are defined in terms of:

- Fission product inventory
- Release fractions
- Timing of release phases
- Radionuclide composition
- Chemical form
- Fuel damage in non-LOCA Design Basis Accidents

The design review of RADTRAD v3.03 will verify that the program conforms to the NRC requirements in each of these areas.

4.1.2 Dose Calculation Requirements

The RADTRAD v3.03 program is required to perform Control Room and Exclusion Area Boundary (EAB) and Low Population Zone (LPZ) dose calculations for the range of design basis accidents as described in NRC Regulatory Guide 1.183 (NRC 2000). The software should be able to use the TID, the AST, or a user specified source release that follows the radionuclide transport within a nuclear facility and the surrounding offsite area.

NRC requirements (10 CFR 50.67) specify the use of the Total Effective Dose Equivalent (TEDE) as the measure of consequence for alternative source term calculations. The calculation of the TEDE should consider all radionuclides, including progeny from the decay of parent radionuclides, which are significant with regard to dose consequences and the released radioactivity. In addition, NRC requires the calculation of the worst two-hour dose when estimating the Exclusion Area Boundary dose. TID dose calculations utilize Thyroid and Whole Body dose consequences. To provide

comparisons with facility dependent UFSAR (TID) dose evaluations the calculation of the Whole Body and Thyroid dose must be available.

RADTRAD Version 3.03 was created to evaluate the eight typical design basis accidents:

- Loss of Coolant Accident (LOCA for BWR or PWR)
- Fuel Handling Accident (FHA for BWR or PWR)
- BWR Control Rod Drop Accident (CRDA)
- BWR Main Steam Line Break Accident (MSLB)
- PWR Main Steam Line Break Accident (MSLB)
- PWR Steam Generator Tube Rupture Accident (SGTR)
- PWR Locked Rotor Accident (LRA)
- PWR Control Rod Ejection Accident (CREA)

The functionality to evaluate these accidents was not available within earlier versions of RADTRAD. The design review of RADTRAD v3.03 will verify that the program conforms to the NRC requirements (NRC 2000) for dose calculation methodology for each of these accidents. It will not address Equipment Qualification Doses which is addressed by the NRC requirements. RADTRAD v3.03 does not produce specific equipment qualification doses calculations.

4.1.3 General Requirements for a Technically Defensible Dose Calculation

To provide a technically defensible accident dose calculation basis, RADTRAD v3.03 must not only use mathematical models and solution algorithms that have been benchmarked with accepted analytical solutions and experimental and empirical data, it must also be well documented: both in terms of the program documentation and in terms of the analysis resulting from the use of the program.

The following are the key elements of RADTRAD v3.03 that will be verified to assure that it provides sufficient acceptable documentation to provide a defensible accident dose calculation basis:

- Equations used to calculate source, transport, removal and decay of radionuclides
- Source terms that are used or can be used
- Solution algorithms to assure that they simulate, with accuracy, radionuclide transport
- Analytical solution methods to assure that they are acceptable for estimating dose consequences
- Source term removal mechanisms including:
  - Containment spray radionuclide removal models
  - Natural deposition models within containment

  - Aerosol deposition models within piping
  - Leakage pathway models from compartments
  - Filtration models
  - Suppression pool models
- The results output to assure that it provides sufficient information to document the dose consequence calculations performed

4.2 Program Design

This V&V will not include a review of the program design. Since RADTRAD is an existing program that has undergone validation and testing in the past (Humphreys 1998; Bixler 1999) and has been in use for a number of years, it was determined that a detailed review of the program was not required. Therefore, no discussion of the program design will be provided in the V&V report.

4.3 Source Code, Program Integration, And Documentation

The review of source code, program integration and documentation will be limited to three primary areas:

- Configuration control of source code changes
- Program installation
- User documentation (Humphreys 1998; Bixler 1999)

These reviews and /or testing will be documented in the V&V report.

4.4 Program Testing

This element of the V&V plan is critical. It is through thorough program testing that all three of the primary objectives of this plan will be accomplished. The testing of RADTRAD v3.03 will be completed by execution of four series of tests. Each of the tests in the series is designed to fulfill one or more of the primary objectives. Recalling, the primary objectives are:

- ***Objective 1*** - Validate RADTRAD v3.03 program revisions
- ***Objective 2*** - Validate RADTRAD v3.03 by benchmarking against other industry recognized programs appropriate for this class of analysis
- ***Objective 3*** - Design review RADTRAD v3.03 to assess its adequacy for performing Total Integrated Dose (TID) and Alternate Radiological Source Term (AST) calculations consistent with NRC Regulatory Guide 1.183

The four series of tests are described below:

- ***Series One*** - This series of tests will utilize a number of NRC acceptance test cases (Humphreys 1998; Bixler 1999). The primary object of this series is Objective 2.

- ***Series Two*** - This series of tests will utilize the NRC rebaselining effort (Callan 1998). The primary objective of this series is Objective 2.

- ***Series Three*** - This series will utilize test cases from a number of sources. The key to each of the sources is that it is believed that they conform to the requirements delineated in NRC Regulatory Guide 1.183 (NRC 2000). The primary objective of this series is Objective 3.

- ***Series Four*** - This series will provide a general test of the Graphic User Interface (GUI). Rather than creating a predefined test matrix for these tests, the functions of the GUI will be fully exercised and the program response will be recorded. The RADTRAD v3.03 GUI will be exercised with regard to: 1) input limits within the code (e.g., 10 entries in a table); 2) input error trapping (e.g., ability to place negative numbers, non-numeric characters, and other incorrect input into the input); and 3) the ability to delete compartments and pathways consistently, (e.g., if the control room is deleted from the compartment then all pathways to/from the control room should be removed and all dose locations within the control room should be removed). Some of the GUI functions may be tested during performance of other test series. If so, this will be documented. The primary objectives of this series are Objectives 1 and 2.

Objective 1 will be accomplished primarily through performance of the aforementioned test series. These test series will test most changes directly and will also demonstrate that the changes do not inadvertently affect other program functions. A separate series has not been developed to validate all of the revisions incorporated into RADTRAD v3.03.

Tables 8-1, 8-2 and 8-3 provide the test matrices for Test Series One, Two and Three respectively.

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
1	2	Verify that a TID puff release of I-131 would leak from containment correctly and match analytic solution. This verifies nuclide inventory instantaneous release. One source compartment will be tested. Only TID Iodine fractions will be evaluated, with one transport pathway	Benchmark Alternate analysis	RADTRAD v2.20 HABIT v1.1 Alternate analysis	< +/- 1%
1a	2	Verify the radionuclide transport between compartments and the control room. This is the same case as Case 1 except that a control room has been added and other Iodine fractions are analyzed along with filter efficiencies.	Benchmark Alternate analysis	RADTRAD v2.20 Alternate analysis	< +/- 1%
2	2	Verify that a puff release of the entire TID source term (I, Xe, and Kr) would leak from the containment and match the analytic solution. This verifies the entire TID (14 nuclide) inventory instantaneous release. This also addresses noble gas releases and balance.	Benchmark Alternate analysis	RADTRAD v2.20 HABIT v1.1 Alternate analysis	< +/- 1%
2a	2	Verify that a puff release of the entire TID (14 nuclide) source term would radioactively decay correctly. This verifies decay of inventory release. This case is the same as case 1 for compartments and pathways.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%

[1] Test Objectives: Objective 1 – Validate v3.03 program revisions, Objective 2 – Validate v3.03 by benchmarking, and Objective 3 – Assess RG 1.183 conformance

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
2b	2	Verify that a puff release of the entire TID (14 nuclide) source term would radioactively decay and daughter correctly. This verifies both decay and appropriate daughtering of inventory releases. This case is the same as case 1 for compartments and pathways. The offsite dose increased to the inclusion of daughtering.	Benchmark	RADTRAD v2.20	< +/- 1%
3	2	Verify that a control room could be added to the calculation and give the same dose results in the environment as case 2, and to add the control room dose calculation. This case utilizes the TID (14 nuclide) inventory, one source compartment, control room filtration and recirculating filters.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
4	2	Verify the effect of natural deposition in containment using TID (14 nuclide) source term. This case is identical to case 3 with respect to source compartment, control room applications, Iodine fractions. Only natural deposition in containment was added (user defined model)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
5	2	Developed to use Henry's natural deposition correlation with TID (14-nuclide) sources term. This case is identical to case 4 with exception that the Henry's natural deposition correlation was used instead of user-defined parameters.	Benchmark	RADTRAD v2.20	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
6	2	Verify timed release of AST I-131 leaking from containment and match analytic solution. AST PWR $^{I-131}$ source term and Iodine Fractions were used in this case. This case is the same as case 1 for compartments and pathways. Only the source term was altered.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
7	2	Verify timed release of entire NUREG-1465 source term for PWRs would leak from containment and match the analytic solution. This case is the same as case 6 with exception that an entire PWR AST 60-nuclide inventory is released (i.e. noble gases, particulates, and halogens.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
7a	2	Verify timed release of entire NUREG-1465 source term for PWRs would radioactively decay correctly. This case is the same as case 7 except that the decay option for the 60-nuclide inventory is turned on. This case demonstrates decay of the PWR AST nuclide inventory.	Benchmark	RADTRAD v2.20	< +/- 1%
7b	2	Verify timed release of entire NUREG-1465 source term for BWRs would leak from containment. This case is the same as case 7 with exception that the source term is for the AST BWR 60 nuclide inventory. The compartments and pathways remain the same as case 7.	Benchmark	RADTRAD v2.20	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
7c	2	Verify timed release of entire NUREG-1465 source term for BWRs would radioactively decay correctly. This case is the same as case 7b except decay option is turned on for the BWR inventory.	Benchmark	RADTRAD v2.20	< +/- 1%
7d	2	Verify timed release of entire NUREG-1465 source term for PWRs would radioactively decay for 10 hr before release. This option tested the delay option specified in RADTRAD. That is the inventory is decayed a certain amount of time before it is released. This case is the same as case 7 except for the delay in release.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
8	2	Verify control room dose calculation for case 7. This case is identical to case 7 with exception that control room is modeled with filtration/recirculating filters.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
9	2	Verify natural deposition in containment using NUREG-1465 source term. This case is the same as case 8 (with control room model) and includes natural deposition of a PWR AST 60 nuclide inventory source term.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
10	2	Verify use of Powers model for natural deposition in containment using NUREG-1465 source term. This case is the same as case 8 with exception that the Powers model for natural deposition was turned on. This case uses a PWR 60	Benchmark	RADTRAD v2.20	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
		nuclide inventory.			
10a	2	Verify use of Henry's correlation for natural deposition in containment using NUREG-1465 source term. This case is the same as case 8 with exception that the Henry's model for natural deposition is turned on. This case uses a PWR 60 nuclide inventory.	Benchmark	RADTRAD v2.20	< +/- 1%
11	2	Verify BWR containment and leak path passing through main steam isolation before going to environment. TID $^{I-131}$ isotope puff source used. This case evaluated other compartments.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
12	2	Verify addition of a control room would not change environmental doses of case 11, and determine control room dose. Case 11 was utilized with addition of control room model.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
13	2	Verify general pipe deposition and that the results of a more detailed model for pipe deposition could be implemented into RADTRAD. Cline model used. Only TID I-131 isotope used for this calculation. One source compartment used with other Iodine fractions.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
13a	2	Not Used			
13b	2	Verify that NUREG-1465 (I-131) source release could be	Benchmark	RADTRAD v2.20	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
		used. This is the same as case 13 with exception to source term.		HABIT v1.1	
14	2	Verify effect of using RADTRAD v3.03 (Brockmann/Bixler) pipe deposition model with TID I-131 puff source term. This case is the same as case 13 with exception that the Brockmann/Bixler piping deposition models are used.	Benchmark	RADTRAD v2.20	< +/- 1%
14a	2	Not Used			
14b	2	Verify use of RADTRAD v3.03 pipe deposition model with NUREG-1465 I-131 timed source term. This case is the same as case 13b with exception that the Brockmann/Bixler piping deposition models are used.	Benchmark	RADTRAD v2.20	< +/- 1%
15	2	Verify BWR containment and leak path passing through ECCS and auxiliary building before exiting to the environment. The NUREG-1465 I-131 timed source term was used. This case included evaluating other compartments.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
16	2	Verify addition of control room will have no effect on environment doses and add control room dose calculation. This case is the same as case 15 with exception to adding on a control room model.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
17	2	Verify the suppression pool decontamination capability. This case included a TID puff release through a suppression pool. This analysis compares the suppression pool DF decontamination with that due to a filter at the same flow and with the same upstream conditions.	Inspection	Mass balance	< +/- 1%
18	2	Not Used			
19	2	Verify advanced PWR design. Containment mixing model with multiple leaks to environment used. The use of NUREG-1465 I-131 isotope for timed release used. This case included sprayed/unsprayed regions and demonstrated the code capability for assuming mixing within containment.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
20	2	Verify entire NUREG-1465 (60 nuclides) source with case 19 assumptions. This case tested release of noble gases within framework of the containment mixing.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
21	2	Verify addition of control room would have no impact on environment doses and add control room dose calculation. This case is the same as case 20 with exception that a control room model with filtration/recirculating filters was added.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%

Table 8-1
Series One – NRC Acceptance Test Cases

Test Case No.	Test Obj.[1]	Description	Validation Method	Expected Result (Humphreys 1998; Bixler 1999)	Acceptance Criteria
22	2	Verify impact of natural deposition in the multi-zoned containment. Case 22 is the same as case 21 with exception to including natural deposition in containment.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
23	2	Verify impact of spray removal coefficient. This case is the same as case 22 with exception that user defined containment spray removal options were utilized.	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 1%
24	2	Developed to examine impact of the Powers' spray removal model. This case is the same as case 23 with addition of evaluating the spray aerosol removal model.	Benchmark	RADTRAD v2.20	< +/- 1%
24a	2	Verify effect of aerosol addition to the source term on the Powers' spray removal model. This case is the same as case 24 with addition of evaluating the aerosol addition.	Benchmark	RADTRAD v2.20	< +/- 1%

Table 8-2
Series Two – NRC Rebaselining Test Cases

Test Case No.	Test Objectives[2]	Accident	Source Term	Rebaseline Plant	Validation Method	Expected Result (Callan 1998)	Acceptance Criteria
1	2	LOCA	TID 14844	Surry (Phase 1)	Benchmark	Surry SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
2	2	LOCA	NUREG 1465	Surry (Phase 1)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 5%
3	2	FHA	TID 14844	Surry (Phase 1)	Benchmark	Surry SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
4	2	FHA	NUREG 1465	Surry (Phase 1)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 5%
5	2	LOCA	TID 14844	Surry (Phase 1)	Benchmark	Surry SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
6	2	LOCA	NUREG 1465	Surry (Phase 1)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 5%
7	2	CRDA	TID 14844	Grand Gulf (Phase 1)	Benchmark	Grand Gulf SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
8	2	CRDA	NUREG 1465	Grand Gulf	Benchmark	RADTRAD v2.20	< +/- 5%

[2] Test Objectives: Objective 1 – Validate v3.03 program revisions, Objective 2 – Validate v3.03 by benchmarking, and Objective 3 – Assess RG 1.183 conformance

Table 8-2
Series Two – NRC Rebaselining Test Cases

Test Case No.	Test Objectives[2]	Accident	Source Term	Rebaseline Plant	Validation Method	Expected Result (Callan 1998)	Acceptance Criteria
				(Phase 1)		HABIT v1.1	
9	2	LOCA	TID 14844	Grand Gulf (Phase 1)	Benchmark	Grand Gulf SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
10	2	LOCA	NUREG 1465	Grand Gulf (Phase 1)	Benchmark	Grand Gulf SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
11	2	FHA (Primary)	TID 14844	Grand Gulf (Phase 1)	Benchmark	Grand Gulf SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
12	2	FHA (Primary)	NUREG 1465	Grand Gulf (Phase 1)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 5%
13	2	FHA (Secondary)	TID 14844	Grand Gulf (Phase 1)	Benchmark	Grand Gulf SER RADTRAD v2.20 HABIT v1.1	< +/- 5%
14	2	FHA (Secondary)	NUREG 1465	Grand Gulf (Phase 1)	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 5%
15	2	LOCA	TID 14844	Surry (Phase 2)	Benchmark	Surry SER Surry UFSAR RADTRAD v2.20	< +/- 5%
16	2	LOCA	NUREG 1465	Surry (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%

Table 8-2
Series Two – NRC Rebaselining Test Cases

Test Case No.	Test Objectives[2]	Accident	Source Term	Rebaseline Plant	Validation Method	Expected Result (Callan 1998)	Acceptance Criteria
17	2	FHA	TID 14844	Surry (Phase 2)	Benchmark	Surry SER Surry UFSAR RADTRAD v2.20	< +/- 5%
18	2	FHA	NUREG 1465	Surry (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%
19	2	CRDA	TID 14844	Grand Gulf (Phase 2)	Benchmark	Grand Gulf UFSAR RADTRAD v2.02	< +/- 5%
20	2	CRDA	NUREG 1465	Grand Gulf (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%
21	2	LOCA	TID 14844	Grand Gulf (Phase 2)	Benchmark	Grand Gulf SER Grand Gulf UFSAR RADTRAD v2.20	< +/- 5%
22	2	LOCA	NUREG 1465	Grand Gulf (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%
23	2	FHA (primary)	TID 14844	Grand Gulf (Phase 2)	Benchmark	Grand Gulf UFSAR RADTRAD v2.02	< +/- 5%
24	2	FHA (primary)	NUREG 1465	Grand Gulf (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%
25	2	FHA (secondary)	TID 14844	Grand Gulf (Phase 2)	Benchmark	Grand Gulf SER Grand Gulf UFSAR RADTRAD v2.20	< +/- 5%
26	2	FHA (secondary)	NUREG 1465	Grand Gulf (Phase 2)	Benchmark	RADTRAD v2.20	< +/- 5%

Table 8-3
Series Three – NRC Regulatory Guide 1.183 Conformance Test Cases

Test Case No.	Test Obj.[3]	NRC Regulatory 1.183 Requirements	Reference Test Case	Validation Method	Expected Result	Acceptance Criteria
1	3	TID-14844 Source Term Release	Series One – Test Case 2	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
2	3	TID-14844 Source Term Release (Decay)	Series One – Test Case 2a	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
3	3	TID-14844 Source Term Release (Decay and Daughtering)	Series One – Test Case 2b	Benchmark	RADTRAD v2.20	< +/- 10%
4	3	TID-14844 Source Term Release (Decay and Daughtering)	Fermi 2 (Howard 1991)	Benchmark	Fermi 2 FHA	< +/- 10%
5	3	NUREG-1465 (AST) Source Term Release (PWR)	Series One – Test Case 7	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
6	3	NUREG-1465 (AST) Source Term Release (PWR) (Decay)	Series One – Test Case 7a	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
7	3	NUREG-1465 (AST) Source Term Release (BWR)	Series One – Test Case 7b	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
8	3	NUREG-1465 (AST) Source Term Release (BWR) (Decay)	Series One – Test Case 7c	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%

[3] Test Objectives: Objective 1 – Validate v3.03 program revisions, Objective 2 – Validate v3.03 by benchmarking, and Objective 3 – Assess RG 1.183 conformance

Table 8-3
Series Three – NRC Regulatory Guide 1.183 Conformance Test Cases

Test Case No.	Test Obj.[3]	NRC Regulatory 1.183 Requirements	Reference Test Case	Validation Method	Expected Result	Acceptance Criteria
9	3	NUREG-1465 (AST) Source Term Release (PWR) (10 hr Delay))	Series One – Test Case 7d	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
10	3	Radionuclide Transport Compartment to Environment	Series One – Test Case 1	Benchmark Alternate Analysis	RADTRAD v2.20 HABIT v1.1 (Bixler 1999)	< +/- 10%
11	3	Radionuclide Transport Compartment to Control Room	Series One – Test Case 1a	Benchmark Alternate Analysis	RADTRAD v2.20 (Bixler 1999)	< +/- 10%
12	3	Radionuclide Transport Compartment to Compartment	Series One – Test Case 11	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
13	3	Radionuclide Transport Mass Balance	Series One – Test Case 23	Inspection	Balanced Masses	< +/- 10%
14	3	Dose Consequence	Series One – Test Case 3	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
15	3	Containment Spray Removal (PWR) (LOCA)	Surry (Gingrich 1998)	Benchmark	RADTRAD v2.20	< +/- 10%
16	3	Containment Spray Removal (BWR) (LOCA)	Grand Gulf (Gingrich 1998)	Benchmark	RADTRAD v2.20	< +/- 10%
17	3	Containment Spray Removal (PWR) (LOCA)	Zion (Gingrich 1998)	Benchmark	RADTRAD v2.20	< +/- 10%

Table 8-3
Series Three – NRC Regulatory Guide 1.183 Conformance Test Cases

Test Case No.	Test Obj.[3]	NRC Regulatory 1.183 Requirements	Reference Test Case	Validation Method	Expected Result	Acceptance Criteria
18	3	Natural Deposition Decontamination Models in Compartments	Series One – Test Case 9	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
19	3	Natural Deposition Decontamination Models in Compartments (Exercise options for gap and vessel release)	None	Inspection	Mass balance	< +/- 10%
20	3	Piping Deposition	Series One – Test Case 13	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
21	3	Containment Leakage (NUREG-1465 (AST), PWR)	Series One – Test Case 7	Benchmark	HABIT v1.1	< +/- 10%
22	3	Filtration (NUREG-1465 (AST), PWR)	Series One – Test Case 15	Benchmark	RADTRAD v2.20 HABIT v1.1	< +/- 10%
23	3	Suppression Pool (TID-14844)	Series One – Test Case 17	Inspection	Mass balance	< +/- 10%
24	3	DBA LOCA (BWR) (TID-14844)	Series Two – Test Case 21	Benchmark	Grand Gulf SER Grand Gulf UFSAR RADTRAD v2.20	< +/- 10%
25	3	DBA LOCA (BWR) (NUREG-1465 (AST))	Series Two – Test Case 22	Benchmark	RADTRAD v2.20	< +/- 10%

Table 8-3
Series Three – NRC Regulatory Guide 1.183 Conformance Test Cases

Test Case No.	Test Obj.[3]	NRC Regulatory 1.183 Requirements	Reference Test Case	Validation Method	Expected Result	Acceptance Criteria
26	3	DBA LOCA (PWR) (TID-14844)	Series Two – Test Case 15	Benchmark	Surry SER Surry UFSAR RADTRAD v2.20	< +/- 10%
27	3	DBA LOCA (PWR) (NUREG-1465 (AST))	Series Two – Test Case 16	Benchmark	RADTRAD v2.20	< +/- 10%
28	3	DBA FHA (7x7) (TID or AST)	Fermi 2 (Heames 2000)	Benchmark	Fermi 2 FHA	< +/- 10%
29	3	DBA FHA (8x8) (TID or AST)	Fermi 2 (Heames 2000)	Benchmark	Fermi 2 FHA	< +/- 10%
30	3	DBA FHA (9x9) (TID or AST)	Fermi 2 (Heames 2000)	Benchmark	Fermi 2 FHA	< +/- 10%
31	3	DBA CRDA (BWR TID)	Grand Gulf Unit 1 (GGNS-1 1998)	Benchmark Alternate Analysis	Grand Gulf CRDA	< +/- 10%
32	3	DBA BWR MSLB	Cooper Nuclear Station (Scientech, Inc. 1999)	Benchmark	CNS MSLB	< +/- 10%
33	3	DBA PWR MSLB	Surry (Callan 1998)	Benchmark	Surry SER of FSAR	< +/- 10%
34	3	DBA PWR MSLB	Surry (Callan 1998)	Benchmark	Surry UFSAR	< +/- 10%

Table 8-3
Series Three – NRC Regulatory Guide 1.183 Conformance Test Cases

Test Case No.	Test Obj.[3]	NRC Regulatory 1.183 Requirements	Reference Test Case	Validation Method	Expected Result	Acceptance Criteria
35	3	DBA SGTR	Indian Point Unit 2 (Milano 2000)	Benchmark	IP2 SGTR	< +/- 10%
36	3	DBA LRA/SRA	Fort Calhoun Station (Stone and Webster 2001)	Benchmark	FCS SRA	< +/- 10%
37	3	DBA CREA	Fort Calhoun Station (Stone and Webster 2001)	Benchmark	FCS CREA	< +/- 10%

4.5 Review of Test Results

Test results will be reviewed to assure that program requirements have been fully tested and that the tests have met the requirements of this V&V plan. Discrepancies will be noted in the V&V Review Report and additional tests, if required, will be performed and also documented. Tests results will be evaluated relative to acceptance criteria as stated in the test matrix. Exceptions will be noted, causes evaluated and potential program limitations, if any, established.

4.6 V&V Report

The results of the RADTRAD v3.03 V&V will be fully documented in a V&V Review Report. The report will provide a clear road map to how the requirements and the objectives of this V&V plan were met. Specific detailed discussion will be provided documenting the results of the design review of the program requirements. Results of the program testing will be summarized. Any areas where the program test does not meet the acceptance criteria will be discussed in detail. Traceability will be provided to all the test case input and results. Finally, the report will summarize the V&V results in terms of conformance with the V&V objectives and limitations, if any, on the use of the program.

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