AREVA

CALCULATION SUMMARY SHEET (CSS)

Document No. 32 - 7012208 - 001 Safety Related: ☐ Yes ☒ No

Title BBNPP TEDE Constant for Normal Gaseous Effluents 2007 to 2011

PURPOSE AND SUMMARY OF RESULTS:

Purpose

The purpose of this calculation is to determine if the value of the TEDE dose type constant, c_{TEDE}, in [1] bounds the years 2007 through 2011.

Summary of Results

This calculation shows that the value c_{TEDE} = 1,259,244 bounds the historical effluents from 2001 to 2011. That value of c_{TEDE} had been calculated in [1] based on gaseous effluents from SSES in the years 2001 through 2006. It also bounds the gaseous effluents from 2007 through 2011.

Revision 001 was created solely for the purpose of removing the "proprietary" wording from the document.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
AIRAD2 V1 R0 HPUX	
ATMODOS2 V1 R0 HPUX	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT SHALL BE VERIFIED PRIOR TO USE

☐ YES

☒ NO

Review Method: ☒ Design Review (Detailed Check)
☐ Alternate Calculation

Signature Block

Name and Title (printed or typed)	Signature	P/R/A and LP/LR	Date	Pages/Sections Prepared/Reviewed/Approved
Ted Messier Principal Scientist	*TA MESSIER* *6/4/2013*	LP		All changes in current revision
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Note: P/R/A designates Preparer (P), Reviewer (R), Approver (A);
LP/LR designates Lead Preparer (LP), Lead Reviewer (LR)

Project Manager Approval of Customer References (N/A if not applicable)

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Mentoring Information (not required per 0402-01)

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N/A				
N/A				

Record of Revision

Revision No.	Pages/Sections/Paragraphs Changed	Brief Description / Change Authorization
000	All	Initial Release
001	All	This revision consisted only of the removal of the "Proprietary" statement from page 1, the removal of the word "Proprietary" from all other pages, and the change to the latest revision of the 0402-01 template.

Table of Contents

Page

List of Tables

Page

1.0 PURPOSE

The purpose of this calculation is to determine if the value of the TEDE dose type constant, c_{TEDE}, in [1] bounds the years 2007 through 2011.

2.0 ANALYTICAL METHODOLOGY

At first the c_{TEDE}, the TEDE dose type constant, for the years 2007 to 2011 is calculated. The constant had been previously evaluated for the period 2001 through 2006 in [1]. The maximum value for the earlier period was 1,259,244. If the value calculated here is less, then the older value will be bounding for worker dose calculations through 2011, since the TEDE is directly proportional to c_{TEDE}.

From section 5.1 of [1] there is the following equation

$$\dot{D}_j(r) = \left(\frac{\dot{D}_j(r_0)}{\chi/Q(r_0)} \right) * Ar^B = c_j r^B$$

Dropping the dose rate portion and canceling the r^B terms we get

$$\left(\frac{\dot{D}_j(r_0)}{\chi/Q(r_0)} \right) * A = c_j$$

Dropping the "j" subscript (since we are only talking about TEDE,) and dropping the location variable "r_0" and simplifying the notation we get

c = D x A / (X/Q)

From reference [1] we have:

A = 38.603

X/Q = 4.36E-5 (sec/m^3)

D = mrem/ year, at 100% occupancy

Therefore, the equation for c_{TEDE} is:

c_{TEDE} (mrem/yr) = D_{TEDE} x 38.603 / (4.36E-5)

D_{TEDE} = sum of the total effective dose from all nuclides released. These TEDE doses are calculated by the ODA2 code suite which calculates the ICRP 26 TEDE.

3.0 ASSUMPTIONS

3.1 Unverified Assumptions

No assumptions requiring verification were used in this calculation.

3.2 Justified Assumptions

There are no justified assumptions introduced in this calculation.

3.3 Modeling Simplifications

There are no modeling simplifications introduced in this calculation.

4.0 CALCULATION INPUTS

4.1 Gaseous Release Data

The following data for historical gaseous releases for the period between 2007 and 2011 were recorded in the Radiological Effluent Release Reports for SSES Units 1 and 2 [2][3][4][5][6].

Table 4-1: Historical Annual Gaseous Release (Ci) Data for SSES Units 1 & 2

Nuclide	2007	2008	2009	2010	2011
H-3	8.94E+01	5.99E+01	3.75E+01	3.10E+01	4.70E+01
N-13	5.81E+01			2.33E+00	
Ar-41	5.59E+00			9.42E-03	
Kr-85					
Kr-85m	5.06E-01			3.00E-04	
Kr-87	7.20E-02			1.98E-03	
Kr-88	5.31E+00			1.04E-03	
Kr-89					
Xe-133	5.58E-01				
Xe133m					
Xe-135	3.39E-02			9.78E-04	
Xe135m	2.05E-01			6.18E-03	
Xe-137	2.38E+00			9.42E-02	
Xe-138	7.93E-01			2.30E-02	
1-131	2.32E-06				
1-133					
1-135					
Cr-51	2.90E-04			1.41E-04	1.61E-04
Mn-54	1.23E-04		5.27E-05		
Fe-59					
Co-57					
Co-58	6.86E-06			4.20E-06	
Co-60	5.86E-04	4.06E-05	1.58E-04	2.00E-05	7.08E-05
Zn-65		2.36E-05			
Sr-89					
Sr-90					
Cs-134					
Cs-137					
Ce-141					
Ce-144					
Nb-95	2.33E-06				
Ba 140					
Ag110m					
As-76					
Na-24					
Tc-99m					

Note: Effluent releases less than the Lower Limit of Detection (LLD) are not reported and are shown a blank in the table and are modeled as 0.0 Ci.

5.0 COMPUTER USAGE

5.1 Software

For this calculation the following two codes were used. ATMODOS2 [7] calculates the internal and external doses from iodine, tritium and gaseous particulate releases. AIRAD2 [8] calculates the effective dose equivalent due to noble gases. Both were run on the HPUX operating system which is more fully described in [7] and [8].

The AIRAD code pedigree is

```
*******************************************************************************
**                      AREVA NP SOFTWARE CONTROL LIBRARY                    **
*******************************************************************************
**                                                                           **
**  SCL ITEM           :  atmodos2                                           **
**  SCL FILE           :  /SCL/atmodos2/atmodos2.e                           **
**  SCL VER/MOD LEVEL  :  01 / 00                                            **
**  DESCRIPTION        :  Generates internal doses from iodine and           **
**  particulate gaseous releases from nuclear power plants (ODA2).           **
**  INSTALLED DATE     :  06/22/06                                           **
**  SAFETY CODE        :  N                                                  **
**  VALIDATION DOC. #  :  1269023649000                                      **
**  CODE SPONSOR       :  STRUM MARK S.                                      **
**  TODAY'S DATE       :  06/22/12                                           **
**  CURRENT TIME       :  12:49:31 PDT                                       **
**                                                                           **
**  HP-UX eng2002 B.11.11 U 9000/800 1402689151 u                            **
**                                                                           **
*******************************************************************************
*******************************************************************************
```

The ATMODOS code pedigree is

```
*******************************************************************************
**                      AREVA NP SOFTWARE CONTROL LIBRARY                    **
*******************************************************************************
**                                                                           **
**  SCL ITEM           :  airad2                                             **
**  SCL FILE           :  /SCL/airad2/airad2.e                               **
**  SCL VER/MOD LEVEL  :  01 / 00                                            **
**  DESCRIPTION        :  Calculates maximum individual whole body, skin,    **
**  beta air, and gamma air doses from noble gases.  Related to ODA2.        **
**  INSTALLED DATE     :  07/05/06                                           **
**  SAFETY CODE        :  N                                                  **
**  VALIDATION DOC. #  :  1269023649000                                      **
**  CODE SPONSOR       :  STRUM MARK S.                                      **
**  TODAY'S DATE       :  06/22/12                                           **
**  CURRENT TIME       :  12:49:32 PDT                                       **
**                                                                           **
**  HP-UX eng2002 B.11.11 U 9000/800 1402689151 u                            **
**                                                                           **
*******************************************************************************
*******************************************************************************
```

These two codes were evaluated by running doses for the year 2006. The results are in file “tst6”. The effective doses were 1.08E-02 mrem for the noble gas dose and 3.51E-01 for “all other gases”. These exactly match the results on pages 30 and 31 of [1]. Therefore, the installation of the codes AIRAD2 and ATMODOS2 used for the present calculation are acceptable. Confirmation of the operating system used for each run is provided in the

"Software Control Library" banner in each output. The operating system matches that in the software release validations [7] and [8].

5.2 Computer Files

The stored files, i.e., in ColdStor, are listed in Table 5-1.

Table 5-1: Computer Files

File in \cold\general-access\32\32-7000000\32-7012208\official			
File Name	**Date/Time**	**Size (bytes)**	**Description**
07run	06/18/2012 15:58	247866	2007 output file
08run	06/18/2012 16:06	236956	2008 output file
09run	06/26/2012 7:33	236885	2009 output file
10run	06/22/2012 15:51	243381	2010 output file
11run	06/18/2012 16:18	236944	2011 output file
fgrlib	03/05/2008 09:58	115138	Nuclide library input file
gr06	06/18/2012 15:45	1039	Gaseous release input file for 2006 (for tst6)
gr07	06/18/2012 15:15	2128	Gaseous release input file for 2007
gr08	06/18/2012 15:27	434	Gaseous release input file for 2008
gr09	06/26/2012 7:30	434	Gaseous release input file for 2009
gr10	06/22/2012 15:41	1644	Gaseous release input file for 2010
gr11	06/18/2012 15:31	434	Gaseous release input file for 2011
pif1	06/18/2012 15:00	313	Program information input file
qrycw	06/18/2012 15:19	1281	Query input file
run07	06/18/2012 15:54	97	UNIX script file for 2007 run
run08	06/18/2012 15:55	97	UNIX script file for 2008 run
run09	06/18/2012 15:55	97	UNIX script file for 2009 run
run10	06/18/2012 15:55	97	UNIX script file for 2010 run
run11	06/18/2012 15:56	97	UNIX script file for 2011 run
SBGSD	11/21/1991 08:26	960	Gaseous site data default input file
SBUFMAX	11/21/1991 08:28	392	Usage factor default input file
tst6	06/18/2012 15:48	244894	2006 test output file
xqcr	06/18/2012 15:21	192	X/Q input file
File in \cold\general-access\32\32-7000000\32-7012208\unofficial			
32-7012208-000 inputs.xls	06/25/2012 10:05	1,973,760	An Excel spreadsheet that was used to develop the ODA2 inputs
32-7012208-000 results.xls	06/26/2012 14:44	35840	An Excel spreadsheet that was used to process the ODA2 outputs

6.0 CALCULATIONS

6.1 Dose Rates

The dose rate results are in Table 6-1. These were calculated by ATMODOS2 and AIRAD2 per section 5.1. Although N-13 was released, in 2007 and 2010, these codes do not calculate the air submersion dose for it. ATMODOS2 does calculate a ground plane dose.

6.2 Dose Rates from N-13

N-13 was release from the plant in two years; 58.1 Ci in 2007 and 2.33 Ci in 2010 per [2] and [5]. Since the AIRAD library does not include N-13, the air submersion dose rates from N-13 were hand-calculated using the dose factors from Federal Guidance Report No. 12 [9]. The effective dose coefficient for air submersion for N-13 is 4.90E-14 in units of (Sv per Bq s m^-3) from page 58 of that reference. This converts units:

D(mrem/yr) = DF (Sv m^3/Bq s) x 0.037 (Bq/pCi) x 1E5 (mrem/Sv) x 1E12 (pCi/Ci) x Q (Ci/yr) x (X/Q) (s/m^3)

= DF (Sv m^3/Bq s) x Q (Ci/yr) x (X/Q) (s/m^3) x 3.7E15 Equation - 1

Equation-1 is validated against the dose rate from 9.68 Ci of Ar-41 released in 2002 which resulted in an Effective dose of 1.02E-1 mrem as calculated by AIRAD2 as shown in pages 24 and 25 of [1]. The DF for Argon from p58 of [9] is 6.5E-14. The following calculation using our equation yields the same answer.

D (mrem/yr) = 6.5E-14 x 9.68 (Ci/yr) x 4.36E-5 x 3.7E15 = 1.02E-01

The dose rates from submersion in air in N-13 are calculated as follows:

D_2007 = 4.9E-14 x 58.1 (Ci/yr) x 4.36E-5 x 3.7E15 = 4.59E-01 mrem/yr

D_2010 = 4.9E-14 x 2.33 (Ci/yr) x 4.36E-5 x 3.7E15 = 1.84E-02 mrem/yr

These N-13 values as calculated by hand were added to the table below.

6.3 c_{TEDE}

The values of c_{TEDE} for each year were calculated according to the equations in section 2.0. The D/(X/Q) results are in Table 6-2. The maximum D/(X/Q) is 28,211. Thus, c_{TEDE} = 38.603 x 28,211 = 1,089,030. This is shown in Table 6-3. Given that the c_{TEDE} in [1] bounds the present value, the former calculation, reference [1], is bounding.

Table 6-1: Dose Rates[a] (mrem/yr) for Normal Effluent Release for 2007-2011

Applicability	Path	Dose Type	2007	2008	2009	2010	2011	Maximum
	NG	TEDE	1.60E-01	0	0	5.50E-04	0	
	I & P	TEDE	6.11E-01	7.49E-02	1.53E-01	4.10E-02	8.88E-02	
	N-13	TEDE	4.59E-01	0	0	1.84E-02	0	
10CFR20	TOTAL	TEDE	1.23E+00	7.49E-02	1.53E-01	6.00E-02	8.88E-02	1.23E+00

a) assumes 100% occupancy, χ/Q = 4.360E-05 sec/m^3

Table 6-2: Dose Rates to χ/Q Ratios[a] for Normal Effluent Release for 2007-2011

Applicability	Path	Dose Type	2007	2008	2009	2010	2011	Maximum
	NG	TEDE	3.67E+03	0.00E+00	0.00E+00	1.26E+01	0.00E+00	
	I & P	TEDE	1.40E+04	1.72E+03	3.51E+03	9.40E+02	2.04E+03	
	N-13	TEDE	1.05E+04	0.00E+00	0.00E+00	4.22E+02	0.00E+00	
10CFR20	TOTAL	TEDE	2.82E+04	1.72E+03	3.51E+03	1.38E+03	2.04E+03	28,211

a) assumes 100% occupancy

Table 6-3: Comparison of c_{TEDE} by Period

	Dose Type	Years	Dose Rate: X/Q ratio	c(j)
10CFR20	TEDE	2001 - 2006	32,620	1,259,244
10CFR20	TEDE	2007 - 2011	28,211	1,089,030
10CFR20	TEDE	2001 - 2011	32,620	1,259,244

7.0 RESULTS

This calculation shows that the value c_{TEDE} = 1,259,244 bounds the historical effluents from 2001 to 2011. That value of c_{TEDE} had been calculated in [1] based on gaseous effluents from SSES in the years 2001 through 2006. It also bounds the gaseous effluents from 2007 through 2011.

8.0 REFERENCES

1. AREVA Document Number 32-9079799-001, "BBNPP Dose Rate Equation for Normal Gaseous Effluents".
2. PPL, Susquehanna Steam Electric Station Units 1 & 2 Radioactive Effluent and Waste Disposal Report-2007 Annual Report, Accession Number, ML081690384.
3. PPL, Susquehanna Steam Electric Station Units 1 & 2 Radioactive Effluent and Waste Disposal Report-2008 Annual Report, Accession Number, ML091390360.
4. PPL, Susquehanna Steam Electric Station Units 1 & 2 Radioactive Effluent and Waste Disposal Report-2009 Annual Report, Accession Number, ML101170304.
5. PPL, Susquehanna Steam Electric Station Units 1 & 2 Radioactive Effluent and Waste Disposal Report-2010 Annual Report, Accession Number, ML11130A140.
6. PPL, Susquehanna Steam Electric Station Units 1 & 2 Radioactive Effluent and Waste Disposal Report-2011 Annual Report, Accession Number, sorted as AREVA Document 38-7012176-000.
7. AREVA Document Software Release Authorization, 2A4.31-2A4-atmodos2-1.0_SRA-000.
8. AREVA Document Software Release Authorization, 2A4.31-2A4-airad2-1.0_SRA-000.
9. EPA-402-R-93-081, Federal guidance Report No. 12, External Exposure to Radionuclides in Air, Water and Soil, Keith F. Eckerman and Jeffrey C. Ryman, Sept 1993.