ENCLOSURE 2

CALCULATION N-4072-001 CCN-9
FUEL HANDLING ACCIDENT INSIDE FUEL HANDLING BUILDING – CONTROL ROOM & OFFSITE DOSES

Southern California Edison Company ENGINEERING CHANGE NOTICE (ECN)/ CALCULATION CHANGE NOTICE (CCN) COVER PAGE	CALC NO. N-4072-001	ECN NO./ PRELIM. CCN NO. N-8	PAGE 1	TOTAL NO. OF PAGES 24
SUMMARY CHANGE ☒ NO ☐ YES	BASE CALC. REV. 6	UNIT 2 & 3	CCN CONVERSION CCN NO. CCN- 9	CALC. REV. 6
	CALCULATION SUBJECT: **Fuel Handling Accident Inside Fuel Handling Building - Control Room & Offsite Doses**			
CALCULATION CROSS-INDEX ☒ New/Updated Index Included ☐ Existing Index is Complete	ENGINEERING SYSTEM NUMBER/PRIMARY STATION SYSTEM DESIGNATOR 1504 & ~~1515~~ 1510 MD / GGA and GKA		Q-CLASS II	
Site Programs/Procedure Impact? ☒ NO ☐ YES, AR No. ______	CONTROLLED PROGRAM OR DATABASE ACCORDING TO SO123-XXIV-5.1 ☐ PROGRAM ☐ DATABASE	PROGRAM/DATABASE NAME(S) ☐ ALSO, LISTED BELOW N/A	VERSION/RELEASE NO.(S) N/A	
10CFR50.59/72.48 Review: AR No. 040700770-08				

1. BRIEF DESCRIPTION OF ECN/CCN

Appendix A is revised to evaluate the radiological consequences at the Exclusion Area Boundary due to the drop of a transfer cask containing 24 Unit 2 (or Unit 3) fuel assemblies into the cask pool of the Unit 2 (or Unit 3) Fuel Handling Building. The drop is assumed to occur prior to the transfer cask being welded closed. Appendix A retains its similar evaluation evaluating the drop of a transfer cask containing 24 Unit 1 fuel assemblies into the cask pool of either the Unit 2 or Unit 3 Fuel Handling Buildings.

Pages Revised:	7, 14, 250 through 261
Pages Added:	262 through 270
Pages Deleted:	None

INITIATING DOCUMENT (ECP, OTHER) AR 040700770-07 Rev. N/A

2. OTHER AFFECTED DOCUMENTS:

☒ YES ☐ NO OTHER AFFECTED DOCUMENTS EXIST AND ARE IDENTIFIED ON ATTACHED FORM 26-503.

3. APPROVED BY: Mark L Drucker 1/16/2006

MARK DRUCKER (PQS T2RE42 & T3EN64)
ORIGINATOR (Print name/sign/date)
Approval requires PQS T3EN64 Qualification Verified: MD
Initial

ESC. N/A

1/16/06
FLS (Signature/date)
Approval requires PQS T3EN64 Qualification Verified: VFN
Initial

T Remick 1/16/06
TOM REMICK (PQS T2RE42 & T3EN64)
IRE (Print name/sign/date)
Approval requires PQS T3EN64 Qualification Verified: TR
Initial

4. CONVERSION TO CCN DATE 1/21/06 Margaret Whiddon
SCE CDM-SONGS

SCE 26-122-1 REV 9 [REFERENCE: SO123-XXIV-7.15]

Site File Copy

N-4072-001

CALCULATION CROSS-INDEX

ECN NO./ PRELIM. CCN NO. N-8	PAGE 2 OF 24
	CCN CONVERSION: CCN NO. CCN- 9

Calculation No. N-4072-001

Sheet 7 of 270

Calc. rev. number and responsible FLS initials and date	INPUTS These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation.		OUTPUTS Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents.		Does the output interface calc/document require revision?	Identify output interface calc/document CCN, ECP, TCN/Rev., or tracking number
	Calc/Document No.	Rev. No.	Calc/Document No.	Rev. No.	YES/NO	
Rev. 6	Procedure SO23-X-7	10				
	Procedure SO23-X-7.2	6				
	AOI SO23-13-20	7				
	Unit 1 Calculation DC-3782	0 & CCN 1				
	Calculation SNM-DBASE-11	11				
	Unit 2 Calculation NFM-2-PH-1216	0				
	Unit 3 Calculation NFM-3-PH-1216	0				
CCN N-8	SO1-207-1-M210	2	UFSAR 2/3-15.10 (Section 15.10.7.3.5)	32	YES	AR 040700770 - 18
VFN 1/16/06	RGR-U2/3-C14	1	DBD-SO23-TR-AA (Section 4.3.17)	7	YES	ECN # A40767

For conservatism, this calculation does not credit FHB airborne iodine and particulate activity removal by Post Accident Cleanup (PACU) Filter Units S2(3)1504ME370 or S2(3)1504ME371.

Table 2.1-1
Fuel Handling Accident Inside the Fuel Handling Building Doses

Location	Criteria (Rem)	Dose (Rem)	
Control Room (event duration dose) [CR isolated at 3 minutes]		10 CFM CR Unfiltered In-leakage 3438 MWt 1.72 Radial Peaking	1000 CFM CR Unfiltered In-leakage 3438 MWt 1.75 Radial Peaking
Thyroid Inhalation	30	5.6	9.3
Beta Skin Immersion	30	1.2	1.2
Whole Body Gamma Immersion and Shine	5	< 0.1	<0.1
EAB (2-hour dose)			
Thyroid Inhalation	75	18.4	18.8
Beta Skin Immersion	no dose criterion	0.1	0.1
Whole Body Gamma Immersion and Shine	6	< 0.1	<0.1
LPZ (event duration dose)			
Thyroid Inhalation	75	0.5	0.5
Beta Skin Immersion	no dose criterion	< 0.1	<0.1
Whole Body Gamma Immersion and Shine	6	< 0.1	<0.1

The EAB dose consequences of a transfer cask drop in the Units 1, 2 or 3 cask loading area are presented in Appendix A. The transfer cask can be loaded with up to 24 Unit 1, 2 or 3 spent fuel assemblies.

A1.0 PURPOSE

A1.1 Task Description

The purpose of this Appendix is to assess the dose consequences of a transfer cask drop in the Unit 1 Spent Fuel Building cask loading area, or a transfer cask drop in the cask pool of either the Unit 2 or Unit 3 Fuel Handling Building. A transfer cask drop is currently not postulated to occur in the Unit 1 spent fuel pool area because a single failure proof crane will be used for all lifts. The Unit 1 calculation is included for completeness. Even though single failure proof cranes will be used at Units 2 and 3 to lift the transfer cask out of the cask pools, a drop can be postulated when the cask is placed on the upper shelf (i.e., step) of the cask pool for lifting yoke change-out, prior to the transfer cask being welded closed. During this evolution, the cask is not restrained and could fall back into the lower portion of the cask pool if an earthquake occurs. The fuel rods from all 24 Unit 1 or Units 2/3 fuel assemblies that may be present in a transfer cask are conservatively assumed to rupture on cask impact with the bottom of the pool. All the radioactive iodine and noble gas remaining in the fuel rod gap volume are expected to be released from the unwelded transfer cask.

The evaluation to assess the dropping of a transfer cask containing Units 2/3 fuel assemblies provides closure for AR Assignment 040700770-07.

A1.2 Dose Acceptance Criteria

Standard Review Plan (SRP) 15.7.5 (Reference A6.2e, Section II.1) states that the radiological consequences of a postulated spent fuel cask drop accident are acceptable if the calculated whole-body and thyroid doses at the exclusion area boundary (EAB) and low population zone (LPZ) outer boundary are "well within" the exposure guideline values of 10 CFR Part 100, paragraph 11 (i.e., 300 rem for the thyroid and 25 rem for the whole-body doses). Per SRP 15.7.5, "well within" means 25 percent or less of the 10 CFR Part 100 exposure guidelines. Per SRP 15.7.5, these "well within" guideline values are 75 rem for the thyroid dose and 6 rem for the whole-body dose. SRP 15.7.5 does not specify a beta-skin dose criterion.

Per Section A5.0, this analysis conservatively models a puff release of activity to the environment. In this model, the sole difference between the exclusion area boundary (EAB) and low population zone (LPZ) doses would be in the modeling of the EAB and LPZ atmospheric dispersion factors (X/Qs). Per Design Input 4.7, the 0 to 2 hour EAB X/Q is approximately two orders of magnitude greater than the 0 to 2 hour LPZ X/Q. Therefore, the EAB doses will be approximately two orders of magnitude greater than the LPZ doses. Since the EAB and LPZ have the same dose acceptance criteria, this analysis will only evaluate the radiological consequence at the EAB.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV
6	N. YACKLE		T. REMICK							
	M. DRUCKER		T. REMICK							

A2.0 RESULTS/CONCLUSIONS AND RECOMMENDATIONS

A2.1 Dropping of a Transfer Cask Containing 24 Unit 1 Fuel Assemblies That Have Decayed for 10 Years

The EAB whole body gamma doses due to a transfer cask drop in the Unit 1 Spent Fuel Building, or a transfer cask drop in the Unit 2 or Unit 3 Fuel Handling Buildings (FHBs) are 0.0094 rem (i.e., < 0.1 rem) and 0.0027 rem (i.e., < 0.1 rem), respectively. The thyroid dose is zero, since all the iodine isotopes have decayed to zero. The whole body gamma and thyroid doses are small compared to the EAB dose criteria specified in Section A1.2, and are less severe than those of the design basis fuel handling accident in the fuel handling building (FHA-FHB) as reported in Section 2.1 Table 2.1-1 (based on the results presented in Section 8.11, Table 8.11-1a).

The EAB beta skin doses for a transfer cask drop at Unit 1 and Units 2/3 are 0.78 rem and 0.22 rem, respectively. These beta skin doses exceed the 0.1 rem design basis FHA-FHB dose reported in Section 2.1 Table 2.1-1. However, as noted in Section A1.2, there is no EAB beta skin dose criterion for a fuel handling accident. Therefore, the EAB beta skin dose need not be documented in the UFSAR or Accident Analysis DBD.

A2.2 Dropping of a Transfer Cask Containing 24 Units 2/3 Fuel Assemblies That Have Decayed for 5 Years

The EAB doses due to the dropping of a transfer cask in the Unit 2 or Unit 3 Fuel Handling Building (FHB) containing 24 Units 2/3 fuel assemblies that have decayed for 5 years are calculated in Sections A8.5 through A8.7. Due to the inherent uncertainties in any dose analysis, the results are rounded up to the nearest 0.1 rem. Doses less than 0.1 rem are reported as such.

The EAB whole body gamma dose due to a transfer cask drop in the Unit 2 or Unit 3 FHB is 0.0045 rem (i.e., < 0.1 rem). The whole body gamma dose meets the EAB 6 Rem dose criterion specified in Section A1.2, and is less severe than that of the design basis FHA-FHB as reported in Section 2.1 Table 2.1-1 (based on the results presented in Section 8.11, Table 8.11-1a).

The EAB thyroid dose due to a transfer cask drop in the Unit 2 or Unit 3 FHB is 0.046 rem (i.e., < 0.1 rem). The thyroid dose meets the EAB 75 rem dose criterion specified in Section A1.2, and is less severe than that of the design basis FHA-FHB as reported in Section 2.1 Table 2.1-1 (based on the results presented in Section 8.11, Table 8.11-1a).

The EAB beta skin doses for a transfer cask drop in the Unit 2 or Unit 3 FHB is 0.373 rem (i.e., rounded up to 0.4 rem). This beta skin dose exceeds the 0.1 rem design basis FHA-FHB dose reported in Section 2.1 Table 2.1-1. However, as noted in Section A1.2, there is no EAB beta skin dose criterion for a fuel handling accident. Therefore, the EAB beta skin dose need not be documented in the UFSAR or Accident Analysis DBD.

A3.0 MODELING ASSUMPTIONS

A3.1 All fuel rods in the 24 assemblies loaded into the canister inside the transfer cask are conservatively assumed to be intact when they are loaded. All the fuel rods are then assumed to rupture as a result of the cask drop.

A3.2 All of the radioactive material released into the Fuel Storage/Fuel Handling Building atmospheres is assumed to be instantaneously released to the outside environment as a puff release. The dose received at the exclusion area boundary (EAB) for a puff release is the same as the integrated dose for a two hour release.

A3.3 A minimum of 10 years has elapsed since permanent discharge from the core for all Unit 1 fuel assemblies that are loaded into the canister/transfer cask.

A3.4 A minimum of 5 years has elapsed since permanent discharge from the core for all Units 2 & 3 fuel assemblies that are loaded into the canister/transfer cask. This minimum decay time is consistent with the Certificate of Compliance for the Units 2/3 Spent Fuel Storage Cask 24PT4-DSC (Reference A6.2c, Section 2.2.c).

A4.0 DESIGN INPUTS

A4.1 The Unit 1 spent fuel pool contains all assemblies off-loaded subsequent to shutdown at the end of Unit 1 Cycle 11. End of Cycle 11 shutdown occurred on November 30, 1992 (Reference A6.2a). All fission gases in the spent fuel rods in the Unit 1 spent fuel pool have therefore decayed for a minimum of 10 years prior to the earliest estimated removal from the spent fuel pools which will occur no earlier than January, 2003.

Per Reference A6.2a, the most recently off loaded Unit 1 spent fuel assembly stored in the Unit 2 spent fuel pool is Assembly G029. It was permanently discharged at the end of Unit 1 Cycle 8 (November 21, 1985).

Per Reference A6.2a, the most recently off loaded Unit 1 spent fuel assemblies stored in the Unit 3 spent fuel pool were permanently discharged at the end of Unit 1 Cycle 10 (June 30, 1990).

The Unit 1 assembly with the highest burnup is located in the Unit 1 spent fuel pool (Reference A6.2a). Since the Unit 1 spent fuel pool contains the highest burned assembly, and the assemblies which have been stored the shortest time since reactor shutdown, the source terms for Unit 1 fuel in the Unit 1 pool bound the source terms for Unit 1 assemblies stored in either the Unit 2 or Unit 3 spent fuel pools.

A4.2 Per Reference A6.1a, Table 1, Column 5, Unit 1 assembly iodine and noble gas radioisotope inventories at reactor shutdown (no decay) are shown in Table A4.1.

Table A4.1
Assembly Iodine and Noble Gas Inventories
at Reactor Shutdown

ISOTOPE	ACTIVITY (A_0) (ci/assy)
I-131	251600
I-132	339500
I-133	468200
I-134	526100
I-135	453500
Xe-131m	2650

ISOTOPE	ACTIVITY (A_0) (ci/assy)
Xe-133m	12700
Xe-133	586600
Xe-135m	140100
Xe-135	189800
Xe-137	437600
Xe-138	435700
Kr-83m	36940
Kr-85m	87900
Kr-85	5120
Kr-87	186600
Kr-88	235000
Kr-89	341400

A4.3 Per Reference 6.4i, Section C.1d, all of the gap activity in the damaged Unit 1 fuel rods is released from the damaged fuel rods. This gap activity consists of 10 percent of the total noble gases other than Krypton-85, 30 percent of the Krypton-85, and 10 percent of the radioactive iodine in the rods at the time of the accident. |

A4.4 The decay constants for the all isotopes listed in Table A4.1 are shown in Table A4.2. The values for all isotopes are taken from References 6.6a (Theoretical Manual).

Table A4.2
Isotopic Decay Constants

ISOTOPE	DECAY CONSTANT (λ) $(sec)^{-1}$
I-131	0
I-132	0.0000843
I-133	0.000009
I-134	0.00022
I-135	0.0000291
Xe-131m	0
Xe-133m	0.000004
Xe-133	0.000002
Xe-135m	0.000738
Xe-135	0.0000212
Xe-137	0.003024
Xe-138	0.0008151
Kr-83m	0.0001052
Kr-85m	0.000043
Kr-85	0
Kr-87	0.0001514
Kr-88	0.0000673
Kr-89	0.003632

A4.5 Per Design Input 4.8, the Kr-85 thyroid inhalation dose conversion factor (DCF_{thy}) is 0.0 rem/curie, the Kr-85 beta skin immersion dose conversion factor (DCF_{bsi}) is 4.246E-02 rem-m^3/curie-sec, and the Kr-85 whole body gamma immersion dose conversion factor (DCF_{wbgi}) is 5.102E-04 rem-m^3/curie-sec.

Per Design Input 4.8, the I-129 thyroid dose conversion factor is 5.92E+06 rem/curie, the I-129 beta-skin immersion dose conversion factor is 3.710E-04 rem-m^3/curie-sec, and the I-129 whole body gamma immersion dose conversion factor is 3.024E-03 rem-m^3/curie-sec.

A4.6 Per Design Input 4.7, the exclusion area boundary (EAB) atmospheric dispersion factor (χ/Q) is 2.72E-04 sec/m^3 for the Units 2/3 Fuel Handling Buildings.

A4.7 Per Reference A6.1a, Design Input 2, the exclusion area boundary (EAB) atmospheric dispersion factor (χ/Q) is 9.50E-04 sec/m^3 for the Unit 1 Fuel Storage Building.

A4.8 Per Design Input 4.1.1, all of the gap activity in the damaged Units 2 & 3 fuel rods is assumed to be released from the damaged fuel rods. Per Design Input 4.1.2, this gap activity consists of 10 percent of the total noble gases other than Krypton-85, 30 percent of the Krypton-85, and 12 percent of the radioactive iodine in the rods at the time of the accident.

A4.9 Per Design Analysis NFM-2/3-PH-1116 (Reference 6.1aa, Section 4.3 and its referenced Table 3.3-1), the Units 2 & 3 single fuel rod radioisotope iodine and noble gas inventory five years after reactor shutdown is:

Iodine-129	1.20E-04 curies/rod
Krypton-85	1.90E+01 curies rod
All other iodine and noble gas isotopes	0.00E+00 curies/rod

Design Analysis NFM-2/3-PH-1116 documents the presence of tritium in an average fuel rod five years after reactor shutdown. However, per Design Input 4.1.1 tritium is not considered in this analysis since Regulatory Guide 1.25 Section C.1d does not require consideration of non-iodine or non-noble gas gap activity releases from damaged fuel rods.

A4.10 Each Unit 2 or Unit 3 fuel assembly contains 236 fuel rods (Reference A6.2d, Item XI.006).

A4.11 Per Assumption 3.10, the EAB breathing rate is 3.47E-04 m^3/sec.

A5.0 METHODOLOGY

All calculations in this Appendix were completed using a spread sheet, or were done by hand using a calculator. The Unit 1 iodine and noble gas radioisotope 10-year decayed assembly inventories were calculated using the following equation for radioactive decay (Reference A6.2b):

$$A = A_0 e^{-\lambda t}$$

Where

A	=	Inventory of isotope A at time t (ci)
A_0	=	Inventory of isotope A at time t = 0 (ci)
λ	=	decay (transformation) constant of isotope A (sec^{-1})
t	=	elapsed time (sec)

The preceding equation is not required when evaluating the dropping of a cask loaded with Unit 2 or 3 fuel. Design Input A4.9 presents the Units 2 & 3 iodine and noble gas radioisotope 5-year decayed fuel rod inventories.

Since a puff release is assumed for this calculation, the beta skin, whole body and thyroid doses received at the EAB for each isotope is given by the following equation:

$$D_{bsi} \text{ or } D_{wbgi} = A_R * \chi/Q * DCF$$

$$D_{thy} = A_R * \chi/Q * BR * DCF_{thy}$$

Where

D	=	Dose (beta skin immersion, whole body gamma immersion or thyroid) (rem)
A_R	=	Inventory released for each isotope (ci)
χ/Q	=	Atmospheric dispersion factor (sec/m^3)
DCF	=	Dose Conversion Factor (beta skin immersion or whole body gamma immersion) ($rem\text{-}m^3/ci\text{-}sec$)
DCF_{thy}	=	Dose Conversion Factor (thyroid inhalation) (rem/ci)
BR	=	Breathing Rate at the EAB (m^3/sec)

The preceding equations are adapted from Reference 6.6a, Section 4.3; terms that are not applicable for a puff release are eliminated.

The inventory released for each isotope is given by the following equations:

$$A_{(assembly)} = A_{(rod)} * N_{(rod)}$$

$$A_R = A_{(assembly)} * n * f$$

Where

$A_{(assembly)}$	=	Assembly decayed inventory (ci/assy)
$A_{(rod)}$	=	Single Fuel Rod decayed inventory (ci/rod)
$N_{(rod)}$	=	Number of fuel rods per assembly (rod/assy)
n	=	Number of assemblies in cask (assy)
f	=	gap fraction (unitless)

A6.0 REFERENCES

A6.1 Calculations

A6.1a SONGS Unit 1 Calculation No. DC-3782, Revision 0, "SONGS 1 E-Planning Doses Due to Fuel Handling Accident", dated 10/29/92, including CCN No. 1 dated 06/02/94.

A6.2 Other Documents

A6.2a SNM-DBASE-10, Software Installation Report, "Special Nuclear Material Database", dated 05/05/99; Appendix C Excerpt including the data base listing for Unit 1.

A6.2b Cember, Herman, "Introduction to Health Physics", Second Edition, Pergamon Press, 1989.

A6.2c Document SO1-207-1-M210, Revision 2,"ISFSI Certificate of Compliance for Spent Fuel Storage Casks - Technical Specifications for the Advanced NUHOMS System Operating Controls and Limits".

A6.2d Document RGR-U2/3-C14, Revision 1,"SONGS Units 2/3 Cycle 14 Reload Ground Rules".

A6.2e NUREG-0800, Standard Review Plan 15.7.5, Revision 2, "Spent Fuel Cask Drop Accidents", July 1981.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
6	N. YACKLE		T. REMICK						
	M. DRUCKER		T. REMICK						

A7.0 NOMENCLATURE

EAB	exclusion area boundary
A_0	Inventory of isotope A at time t = 0 (ci)
λ	decay (transformation) constant of isotope A (sec^{-1})
DCF	dose conversion factor
DCF_{bsi}	dose conversion factor, beta skin immersion ($rem\text{-}m^3$/curie-sec)
DCF_{wbgi}	dose conversion factor, whole body gamma immersion ($rem\text{-}m^3$/curie-sec)
DCF_{thy}	dose conversion factor, thyroid inhalation (rem/ci)
BR	breathing rate at the EAB (m^3/sec)
χ/Q	atmospheric dispersion factor (sec/m^3)
A	Inventory of isotope A at time t (ci)
t	elapsed time (sec)
D	Dose (beta skin immersion, whole body gamma immersion, or thyroid) (rem)
A_R	Inventory released for each isotope (ci)
$A_{(assembly)}$	Assembly decayed inventory (ci/assy)
$A_{(rod)}$	Single Fuel Rod decayed inventory (ci/rod)
n	Number of assemblies in cask (assy)
$N_{(rod)}$	Number of fuel rods per assembly (rod/assy)
f	gap fraction (unitless)
D_{wbgi}	whole body gamma immersion dose (rem)
D_{bsi}	beta skin immersion dose (rem)
D_{thy}	thyroid inhalation dose (rem)

assy	assembly
ci	curie
sec	second
m	meter

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
6	N. YACKLE		T. REMICK						
	M. DRUCKER		T. REMICK						

A8.0 COMPUTATIONS

The Unit 1 iodine and noble gas radioisotope assembly inventory 10 years after reactor shutdown are calculated in a spread sheet using the equation for radioactive decay provided above. The results are shown in Table A8.1.

TABLE A8.1
Unit 1 Iodine and Noble Gas Assembly Inventory
10 Years After Reactor Shutdown

ISOTOPE	UNIT 1 ASSEMBLY ACTIVITY ($A_{(assembly)}$) (ci/assy)
I-131	0
I-132	0
I-133	0
I-134	0
I-135	0
Xe-131m	0
Xe-133m	0
Xe-133	0
Xe-135m	0
Xe-135	0
Xe-137	0
Xe-138	0
Kr-83m	0
Kr-85m	0
Kr-85	2679
Kr-87	0

ISOTOPE	UNIT 1 ASSEMBLY ACTIVITY ($A_{(assembly)}$) (ci/assy)
Kr-88	0
Kr-89	0

Since all Unit 1 iodine isotopes and all noble gas isotopes except Kr-85 have decayed to zero after 10 years of decay, only the beta skin and whole body immersion doses due to Kr-85 are calculated.

The Units 2&3 iodine and noble gas radioisotope assembly inventory 5 years after reactor shutdown are calculated in Table A8.2 by the following equation introduced in Section A5.0. As a sample calculation, the Units 2 and 3 assembly Krypton-85 activity after 5 years of decay is:

$$A_{(assembly)} = A_{(rod)} * N_{(rod)} = (19.0 \text{ ci/rod}) * (236 \text{ rods/assy}) = 4.484E+03 \text{ ci/assy}$$

TABLE A8.2
Units 2&3 Iodine and Noble Gas Assembly Inventory
5 Years After Reactor Shutdown

ISOTOPE	UNITS 2&3 FUEL ROD ACTIVITY AT 5 YEARS [Assumption A3.4] (ci/rod)	FUEL RODS PER UNITS 2&3 FUEL ASSEMBLY [Design Input A4.10] (rods/assy)	UNITS 2&3 ASSEMBLY ACTIVITY AT 5 YEARS (ci/assy)
I-129	1.20E-04	236	2.832E-02
KR-85	1.90E+01	236	4.484E+03

A8.1 Dropped Cask of Unit 1 Fuel in the Unit 1 Fuel Building, Unit 1 EAB Whole Body Gamma Immersion Dose

Per Table A8.1 above, Assumption A3.1 and Design Inputs A4.3, A4.5 and A4.7:

$A_{(assmbly)}$ =Assembly decayed inventory = 2.679E+03 ci/assy

n =Number of assemblies in cask = 24 assy

f =gap fraction = 30%/100% = 0.30

χ/Q =9.50E-04 sec/m^3

DCF_{wbgi}=5.102E-04 rem-m^3/curie-sec.

And

$$D_{wbgi} = A * \chi/Q * DCF_{wbgi}$$

$$D_{wbgi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{wbgi}$$

$$D_{wbgi} = 2.679E{+}03 \text{ ci/assy} * 24 \text{ assy} * 0.30 * 9.50E{-}04 \text{ sec/m}^3 * 5.102E{-}04 \text{ rem-m}^3\text{/curie-sec}$$

$$D_{wbgi} = 9.35E{-}03 \text{ rem}$$

A8.2 Dropped Cask of Unit 1 Fuel in the Unit 1 Fuel Building, Unit 1 EAB Beta Skin Immersion Dose

Per Table A8.1 above, Assumption A3.1 and Design Inputs A4.3, A4.5 and A4.7:

$A_{(assmbly)}$=Assembly decayed inventory =2.679E+03 ci/assy

n =Number of assemblies in cask =24 assy

f =gap fraction = 30%/100% =0.30

χ/Q =9.50E-04 sec/m^3

DCF_{bsi} =4.246E-02 rem-m^3/curie-sec.

And,

$D_{bsi} = A * \chi/Q * DCF_{bsi}$

$D_{bsi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{bsi}$

D_{bsi} = 2.679E+03 ci/assy *24 assy*0.30*9.50E-04 sec/m^3*4.246E-02 rem-m^3/curie-sec

D_{bsi} = 7.77E-01 rem

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV
6	N. YACKLE		T. REMICK							
	M. DRUCKER		T. REMICK							

A8.3 Dropped Cask of Unit 1 Fuel in the Unit 2 or 3 Fuel Handling Building, Unit 2/3 EAB Whole Body Gamma Immersion Dose

Per Table A8.1 above, Assumption A3.1 and Design Inputs A4.3, A4.5 and A4.6:

$A_{(assmbly)}$ = Assembly decayed inventory = 2.679E+03 ci/assy

n =Number of assemblies in cask = 24 assy

f =gap fraction = 30%/100% = 0.30

χ/Q =2.72E-04 sec/m^3

DCF_{wbgi}=5.102E-04 rem-m^3/curie-sec.

And,

$D_{wbgi} = A * \chi/Q * DCF_{wbgi}$

$D_{wbgi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{wbgi}$

D_{wbgi} = 2.679E+03 ci/assy *24 assy*0.30*2.72E-04 sec/m^3*5.102E-04 rem-m^3/curie-sec

D_{wbgi} = 2.68E-03 rem

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
6	N. YACKLE		T. REMICK						
	M. DRUCKER		T. REMICK						

A8.4 Dropped Cask of Unit 1 Fuel in the Unit 2 or 3 Fuel Handling Building, Unit 2/3 EAB Beta Skin Immersion Dose

Per Table A8.1 above, Assumption A3.1 and Design Inputs A4.3, A4.5 and A4.6:

$A_{(assmbly)}$=Assembly decayed inventory =2.679E+03 ci/assy

n =Number of assemblies in cask =24 assy

f =gap fraction = 30%/100% =0.30

χ/Q =2.72E-04 sec/m^3

DCF_{bsi} =4.246E-02 rem-m^3/curie-sec.

And,

$D_{bsi} = A * \chi/Q * DCF_{bsi}$

$D_{bsi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{bsi}$

D_{bsi} = 2.679E+03 ci/assy *24 assy*0.30*2.72E-04 sec/m^3*4.246E-02 rem-m^3/curie-sec

D_{bsi} = 2.23E-01 rem

A8.5 Dropped Cask of Units 2&3 Fuel in the Unit 2 or 3 Fuel Handling Building, Unit 2/3 EAB Whole Body Gamma Immersion Dose

Table A8.5-1 documents the input values and resultant whole body gamma immersion doses due to the release of Iodine-129 and Krypton-85 from the damaged Units 2&3 fuel present in the dropped cask.

As a sample calculation, the Krypton-85 whole body gamma immersion dose is:

$$D_{wbgi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{wbgi}$$

$$D_{wbgi} = 4.484E{+}03 \text{ ci/assy} * 24 \text{ assy} * 0.30 * 2.72E{-}04 \text{ sec/m}^3 * 5.102E{-}04 \text{ rem-m}^3\text{/curie-sec}$$

$$D_{wbgi} = 4.5E{-}03 \text{ rem}$$

The total whole body gamma immersion dose at the EAB due to a dropped cask of Units 2&3 fuel in the Unit 2 or 3 FHB is 4.5E-03 rem.

TABLE A8.5-1

Isotope	U23 Assembly Activity [Table A8.2] (ci/assy)	Number of Damaged Assemblies per Cask [Sect. A3.1] (assy/cask)	Damaged Fuel Rod Gap Release Fraction [Sect. A4.8] (unitless)	U23 to EAB Atmospheric Dispersion Factor [Sect. A4.6] (sec/m^3)	Whole Body Gamma Immersion DCF [Sect. A4.5] (rem-m^3/ci-s)	Whole Body Gamma Immersion Dose (rem)
I-129	2.832E-02	24	0.12	2.72E-04	3.024E-03	6.7E-08
Kr-85	4.484E+03	24	0.30	2.72E-04	5.102E-04	4.5E-03
TOTAL	-	-	-	-	-	4.5E-03

A8.6 Dropped Cask of Units 2&3 Fuel in the Unit 2 or 3 Fuel Handling Building, Unit 2/3 EAB Beta Skin Immersion Dose

Table A8.6-1 documents the input values and resultant beta skin immersion doses due to the release of Iodine-129 and Krypton-85 from the damaged Units 2&3 fuel present in the dropped cask.

As a sample calculation, the Krypton-85 beta-skin immersion dose is:

$$D_{bsi} = A_{(assmbly)} * n * f * \chi/Q * DCF_{bsi}$$

$$D_{bsi} = 4.484E+03 \text{ ci/assy} * 24 \text{ assy} * 0.30 * 2.72E-04 \text{ sec/m}^3 * 4.246E-02 \text{ rem-m}^3\text{/curie-sec}$$

$$D_{bsi} = 3.73E-01 \text{ rem}$$

The total beta skin immersion dose at the EAB due to a dropped cask of Units 2&3 fuel in the Unit 2 or 3 FHB is 3.73E-01 rem.

TABLE A8.6-1

Isotope	U23 Assembly Activity [Table A8.2] (ci/assy)	Number of Damaged Assemblies per Cask [Sect. A3.1] (assy/cask)	Damaged Fuel Rod Gap Release Fraction [Sect. A4.8] (unitless)	U23 to EAB Atmospheric Dispersion Factor [Sect. A4.6] (sec/m³)	Beta Skin Immersion DCF [Sect. A4.5] (rem-m³/ci-s)	Beta Skin Immersion Dose (rem)
I-129	2.832E-02	24	0.12	2.72E-04	3.710E-04	8.23E-09
Kr-85	4.484E+03	24	0.30	2.72E-04	4.246E-02	3.73E-01
TOTAL	-	-	-	-	-	3.73E-01

A8.7 Dropped Cask of Units 2&3 Fuel in the Unit 2 or 3 Fuel Handling Building, Unit 2/3 EAB Thyroid Inhalation Dose

Table A8.7-1 documents the input values and resultant thyroid inhalation dose due to the release of Iodine-129 and Krypton-85 from the damaged Units 2&3 fuel present in the dropped cask.

As a sample calculation, the Iodine-129 thyroid inhalation dose is:

$$D_{thy} = A_{(assmbly)} * n * f * \chi/Q * BR * DCF_{thy}$$

$$D_{thy} = 2.832E\text{-}02 \text{ ci/assy}*24 \text{ assy}*0.30*2.72E\text{-}04 \text{ sec/m}^3*3.47E\text{-}04 \text{ m}^3\text{/sec}*5.92E\text{+}06 \text{ rem/curie}$$

$$D_{thy} = 4.6E\text{-}02 \text{ rem}$$

The total thyroid inhalation dose at the EAB due to a dropped cask of Units 2&3 fuel in the Unit 2 or 3 FHB is 4.56E-02 rem.

TABLE A8.7-1

Isotope	U23 Assembly Activity [Table A8.2] (ci/assy)	Number of Damaged Assemblies per Cask [Sect. A3.1] (assy/cask)	Damaged Fuel Rod Gap Release Fraction [Sect. A4.8] (unitless)	U23 to EAB Atmospheric Dispersion Factor [Sect. A4.6] (sec/m^3)	Breathing Rate [Sect A4.11] (m^3/sec)	Thyroid Inhalation DCF [Sect. A4.5] (rem/ci)	Thyroid Inhalation Dose (rem)
I-129	2.832E-02	24	0.12	2.72E-04	3.47E-04	5.92E+06	4.6E-02
Kr-85	4.484E+03	24	0.30	2.72E-04	3.47E-04	0.00	0.00
TOTAL	-	-	-	-	-	-	4.6E-02