

ICRP-60

가

Radiological Consequences from KNGR Design Basis Accidents Based on the Framework of Alternative Source Term and ICRP-60

360-9

NRC DBA TID-14844 Regulatory Guide 1.4, 1.25, 1.77 NUREG-1465 Regulatory Guide 1.183 1995 2000 , NUREG-1465

1990 ICRP 가

ICRP-60 DBA ICRP-60 가 가 DBA 가 가

Abstract

In 1995 and 2000, NRC issued the accident source term of NUREG-1465[1] and Regulatory Guide 1.183[2], as an alternative source term (AST) to TID-14844[3] and Regulatory Guide 1.4[4], 1.25[5], and 1.77[6], to assess radiation dose from design basis accidents (DBA). The alternative source term of NUREG-1465 was developed as a representative source term to reflect the insight of a few ten years research on severe accidents. ICRP did an important role to develop and to change the standards on radiation protection. In 1990, ICRP published ICRP-60[7] as a baseline to assess radiological effects on human body and published succeeding ICRP recommendations. The methodology to assess the radiation exposure to human body has been changed with improvement of knowledge on interactions between radiation exposure and human body. In Korean Next Generation Reactor (KNGR) Project, the framework of AST and ICRP-60 is being applied to assess radiation doses from DBAs. In this paper, the radiation doses from DBAs were estimated based on the different frameworks of accident source term and dose assessment. The results were compared each other and the design margin of KNGR was evaluated.

1.

NRC DBA
TID-14844 Regulatory Guides 1.4,
1.25 1.77
NUREG-1465 Regulatory Guide 1.183
1995 2000
NUREG-1465

LOCA

가

ICRP . 1990 ICRP
가

ICRP-60 .
DBA 가

ICRP-60
가 .

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ICRP-60 가

가

ICRP-60 가

2. DBA

가

가

(Exclusion Area Boundary, EAB)가

가

가

(DBA)

가가

DBA

- (Steam Line Break, SLB)
- (Feedwater Line Break, FWLB)
- (RCP Locked Rotor, RCP LR)
- (Control Rod Ejection Accident, CEA)
- (Letdown Line Break, LDLB)
- (S/G Tube Rupture, SGTR)
- (LOCA)
- (Fuel Handling Accident, FHA)

2.1

가

DBA

가

가

가

- LOCA
- DBA LOCA
- 가

$$\dot{Q}_{in} = f_{rel} \cdot A_{core}$$

(TID-14844

Reg. Guide 1.4)

NRC

\dot{Q}_{in} :
 f_{rel} :

. NRC

NUREG-1465

NUREG-1465

가

NUREG-

1465

2-1

2-
 LOCA

가

1

2-2

Non-LOCA

- Non-LOCA
 Non-LOCA

2-3

2-2

2-3

가

LOCA

2-2

$$C_{rcs} = F_{pp} (f_{fm} + f_{ff} \cdot f_{gap}) \frac{A_{core}}{M_{rcs}} + C_{rcs-TS}$$

가

가

$$C_{rcs} = F_{pis} \cdot C_{rcs-TS}$$

가

, f_{fm} , f_{ff} , f_{gap}

가

F_{pp} , F_{pis} Power Peaking Factor
 Iodine Peaking Factor

2-1.

. C_{rcs} , C_{rcs-TS}

Tech.

Spec.

M_{rcs}

LOCA	TID-14844 Reg. Guide 1.4	NUREG-1465
Non-LOCA	Reg. Guide 1.25 Reg. Guide 1.77 SRP 15	Reg. Guide 1.183 SRP 15.0.1

2-2. LOCA

		TID-14844	NUREG-1465
		PWR BWR	PWR, BWR
		100%	100%
			(1.8hr)
		3	8
()		100% 50% -	100% 40% 30% (Cs, Rb)
		91 % 4 % 5 %	4.85 % 0.15 % 95 %
		ANSI/ANS-56.5 SRP-6.5.2	NUREG/CR-5966 NUREG/CR-6189

NUREG/CR-5966[8] NRC
NUREG/CR-6189[9]

Non-LOCA 2-3

(Cs, Rb) 가

2.2 가

(EAB), DBA (LPZ) 가

2-3. Non-LOCA

		1]	2]
		R.G 1.25 R.G 1.77	R.G 1.183
()	Kr-85 N.G I-131	10 (30) % 10 % 10 % 10 % -	10 % 5 (10) % 8 (10) % 5 (10) % 12 (0) %
(/)		91 % 4 % 5 %	4.85 % 0.15 % 95 %
(/)		99.75 % 0.25 % -	97 % 3 % -

- ()
 $D_{off,in} = (x/Q)_{off} \cdot BR \cdot \sum_i (F_{i,in} \cdot Q_i)$
 - ()
 $D_{off,ex} = (x/Q)_{off} \cdot \sum_i (F_{i,ex} \cdot Q_i)$
- $D_{off,in}, D_{off,ex} :$
- $D_{on,in}, D_{on,ex} :$
- $F_{i,in}, F_{i,ex} :$ i () ()
- $x/Q_{off} :$
- $Q_i :$
- $BR :$

1] FHA
2] CEA

DBA

DBA
 ,
 ,
 ,
 가
 가
 (ICRP) 가 ICRP
 가 ICRP
 가 2-4
 , DBA 가
 2-5
 2-6

2-5.

(: rem/Ci)

I)	TID-14844 R.G 1.109 [12]		FGR No.11 [13]	ICRP-68 [14] ICRP-71 [15]
I 131E	1.48E+06	2.56E+03	-	7.40E+04
I 132E	5.35E+04	1.45E+02	-	1.15E+03
I 133E	4.00E+05	5.65E+02	-	1.48E+04
I 134E	2.50E+04	7.69E+01	-	5.55E+02
I 135E	1.24E+05	3.21E+02	-	3.40E+03
I 131O	-	-	-	5.55E+04
I 132O	-	-	-	7.03E+02
I 133O	-	-	-	1.15E+04
I 134O	-	-	-	1.85E+02
I 135O	-	-	-	2.52E+03
I 131P	-	-	3.29E+04	2.81E+04
I 132P	-	-	3.81E+02	3.55E+02
I 133P	-	-	5.85E+03	5.55E+03
I 134P	-	-	1.31E+02	1.78E+02
I 135P	-	-	1.23E+03	1.22E+03
Rb 86	-	7.37E+03	3.44E+03	3.44E+03
Cs134	-	9.10E+04	4.63E+04	2.52E+04
Cs136	-	1.38E+04	7.33E+03	4.81E+03
Cs137	-	5.35E+04	3.19E+04	1.78E+04

¹⁾ E : elemental, O : organic, P : particulate

2-4. 가

가	가		
가	ICRP-9[10] (1959)	ICRP-26[11] (1977)	ICRP-60 (1990)
		가 가 ALARA	가
가	가		가
		가	¹⁾
	TID-14844 R.G 1.4 R.G 1.109	ICRP-30 EPA FGR No.11 EPA FGR No.12	ICRP-68 ICRP-71 ICRP-72 ICRP-74

¹⁾ =

2-6.

(: rem-m³/Ci-sec)

I)	R.G 1.4 R.G 1.109		FGR No.12 [16]	ICRP-72 [17]
KR85M	4.63E-02	2.49E-02	2.77E-02	2.53E-02
KR85	4.25E-02	5.58E-04	4.40E-04	9.42E-04
KR87	3.08E-01	1.96E-01	1.52E-01	1.46E-01
KR88	7.51E-02	4.84E-01	3.77E-01	3.60E-01
XE131M	1.51E-02	5.02E-03	1.44E-03	1.37E-03
XE133M	3.15E-02	1.04E-02	5.07E-03	4.71E-03
XE133	9.70E-03	1.13E-02	5.77E-03	5.14E-03
XE135M	2.25E-02	1.08E-01	7.55E-02	6.85E-02
XE135	5.90E-02	6.16E-02	4.40E-02	4.11E-02
XE138	1.31E-01	2.74E-01	2.13E-01	2.01E-01
I 131E	-	9.51E-02	-	-
I 132E	-	5.65E-01	-	-
I 133E	-	1.51E-01	-	-
I 134E	-	6.51E-01	-	-
I 135E	-	3.89E-01	-	-
I 131O	-	-	-	-
I 132O	-	-	-	-
I 133O	-	-	-	-
I 134O	-	-	-	-
I 135O	-	-	-	-
I 131P	-	-	6.73E-02	-
I 132P	-	-	4.14E-01	-
I 133P	-	-	1.09E-01	-
I 134P	-	-	4.81E-01	-
I 135P	-	-	2.95E-01	-
Rb 86	-	1.78E-02	1.78E-02	-
Cs134	-	3.89E-01	2.80E-01	-
Cs136	-	5.42E-01	3.92E-01	-
Cs137	-	5.84E-01	4.48E-01	-

¹⁾ M : meta stable, E : elemental, O : organic,
P : particulate

3. DBA

가

DBA

가

3-1

4. DBA

가

DBA

ICRP-60

[22].

DBA

1997 1

가

가

ICRP-26

가

, DBA

2000-08 [18]가

4.1

가

TID-14844 Reg. Guide 1.4

2

DBA

가

DBA

가

4-1

3가

[19].

4-1

Case A

가

98-12 [20]

2001-02 [21]

ICRP-60

(Thyroid Dose)

가

(Whole Body Dose)

가

Case B

(1997

)

가

ICRP-60

()

(Total

3-1. DBA

가

Effective Dose Equivalent)

Case C

가

가		
(LOCA)	2000-08	10CFR50 NUREG-1465 R.G 1.183
(Non-LOCA)	SRG 15 ¹⁾	R.G 1.183 SRP 15.0.1
	SRG 15 (,)	R.G 1.183 SRP 15.0.1 ()

¹⁾

Reg.

Guide SRP 15

. Case C

(Total Effective

Dose)

가

가

• 2000

(EAB)

가

•

EAB

(0-

- 2hr) : $8.92 \times 10^{-4} \text{ sec/m}^3$
- : 0.15 vol%/day
- Non-LOCA 가 , Case B C
- Iodine Spiking , Tech. Spec.
- LOCA (Spray Removal Containment Mixing) 2-2 Case A SRP-6.5.2 Case B Case C NUREG/CR-5966[8] STAR NAUA
- Non-LOCA 4-2 .
- Non-LOCA 2 4-3 [23,24].
- LOCA STARDOSE [25] Case A 2 , Case B Case C 가 2 가 , Non-LOCA 가
- Case C FGR No.12

4.2 가

DBA 4-1 , 4-4 가 EAB 4-5

4-2 . Case A , Case B C

4-1. 가

Case			
Case A	R.G 1.4	ICRP-9	
Case B	R.G 1.183	ICRP-26	
Case C	R.G 1.183	ICRP-60	

4-2. ¹⁾

RCS->SG->	SG Tube	Dried	Undried
		1	Flashed : 1 Unflashed : 100
		1	100
RCS->		Flashed : 1 Unflashed : 100	
RCS->			
SFP->	500		

¹⁾ 1

4-3. Non-LOCA (2)

DBA	RCS		
	(%)	(lbm)	
SLB(FP) ¹⁾	1.0	540	RCS->SG
SLB(ZP) ²⁾	0.0	540	RCS->SG
FWLB	0.0	540	RCS->SG
RCP LR	4.0	540	RCS->SG
CEA	15.0	3772	RCS->CTMT 540
LDLB	0.0	41700	RCS->Env 540
SGTR(LOOP)	0.0	72200	RCS->SG
SGTR (LOOP+SF)	0.0	289700	RCS->SG
FHA ³⁾	0.415	6.3E+05	SFP->FHA

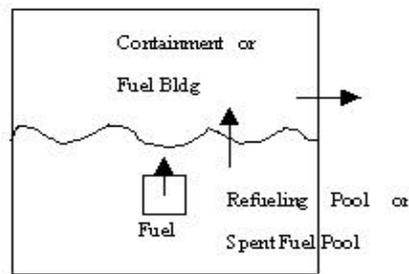
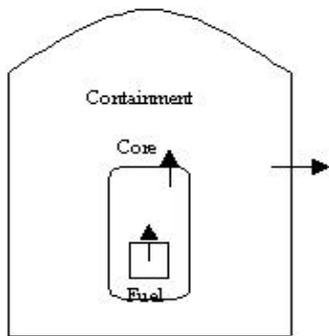
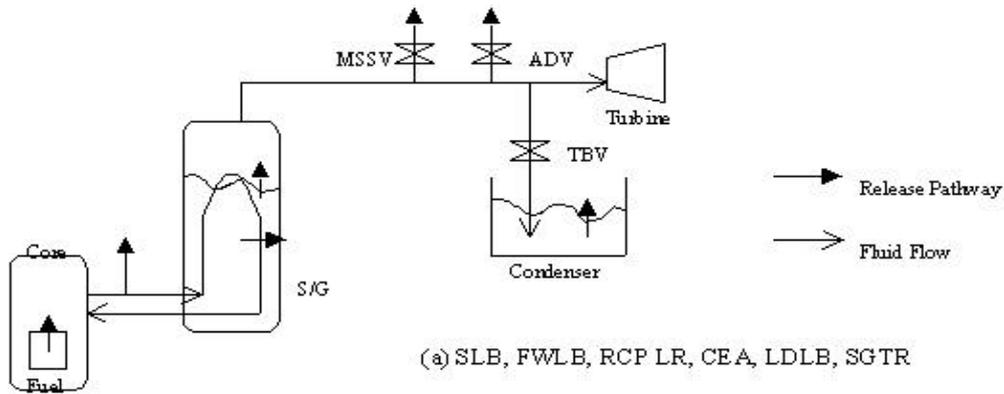
¹⁾ FP : SLB during Full Power Operation
²⁾ ZP : SLB during Zero Power Operation
³⁾ FHA 1

4-4. 가 DBA 가

Case	I ¹⁾	DBA (Ci) ²⁾				
		LOCA	SLB(FP)	FWLB	CEA	SGTR(LOOP)
Case A	Xe-133	3.88E+04	1.19E+03	9.70E+01	4.87E+03	1.29E+04
	I-131E	1.09E+03	2.94E+02	5.55E+01	2.41E+01	6.22E+01
	I-131O	1.84E+02	1.39E+00	1.44E-01	5.80E+00	3.83E+00
	I-131P	6.29E+01	-	-	-	-
	Cs-137	-	-	-	-	-
Case B Case C	Xe-133	1.86E+04	5.49E+02	9.70E+01	4.87E+03	1.29E+04
	I-131E	3.20E+01	2.34E+02	5.40E+01	2.34E+01	6.05E+01
	I-131O	5.55E+00	1.35E+01	1.73E+00	6.96E+01	4.60E+01
	I-131P	6.23E+02	-	-	-	-
	Cs-137	8.76E+01	5.59E+01	1.85E-01	2.00E-03	6.76E-01

¹⁾ E : Elemental, O : Organic, P : Particulate

²⁾ 2 (LOCA 가 2)

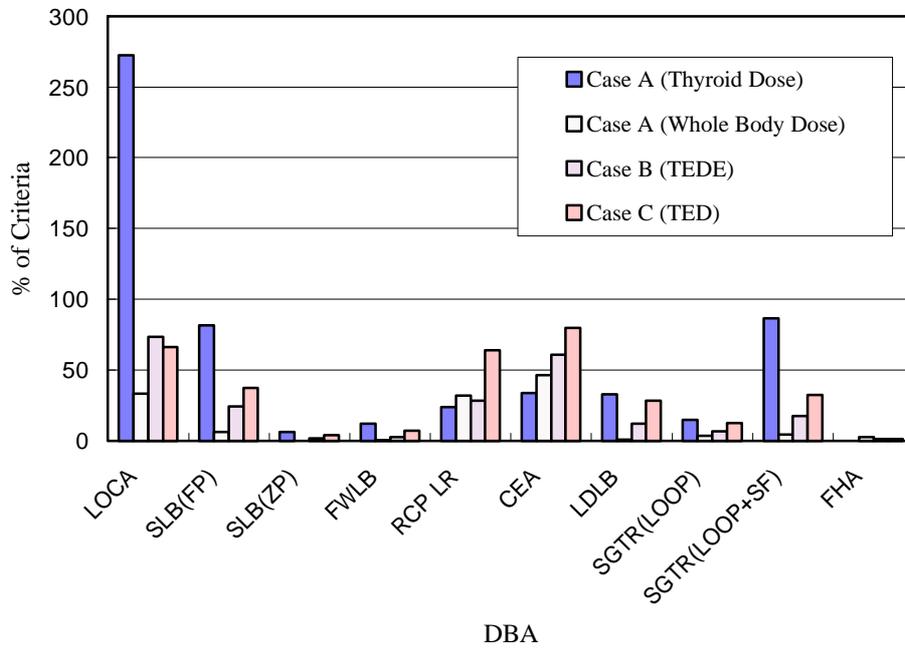


4-1. DBA

4-5. 가 DBA 가

DBA		(rem)		¹⁾ (rem)		/ (rem)		
		Case A		Case A		Case B	Case C	
		LOCA	817.5	300.0	8.3	25.0	18.3	16.5
SLB	Full Power	244.1	300.0	1.5	25.0	6.0	9.3	25.0
	Zero Power	18.4	300.0	0.022	25.0	0.4	0.9	25.0
FWLB		35.9	300.0	0.04	25.0	0.7	1.7	25.0
RCPLR		7.1	30.0	0.8	2.5	0.7	0.9	2.5
CEA		25.2	75.0	2.9	6.25	3.8	5.0	6.25
LDLB		9.8	30.0	0.02	2.5	0.3	0.7	2.5
SGTR	LOOP	44.3	300.0	0.8	25.0	1.6	3.1	25.0
	LOOP+SF	259.0	300.0	1.1	25.0	8.0	16.0	25.0
FHA		0.07	75.0	0.15	6.25	0.08	0.08	6.25

¹⁾



4-2. DBA 가

6.
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 - 4) Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors", Rev.2, US NRC, 1974.
 - 5) Regulatory Guide 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors", US NRC, 1972.
 - 6) Regulatory Guide 1.77, "Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors", US NRC, 1974.
 - 7) ICRP Publication 60, "1990 Recommendations of the International Commission on Radiological Protection", ICRP, 1991.
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 - 9) NUREG/CR-6189, "A Simplified Model of Aerosol Removal by Natural Processes in Reactor Containment", US NRC, 1996.
 - 10) ICRP Publication 9, "Recommendations of the International Commission on Radiological Protection", ICRP, 1966.
 - 11) ICRP Publication 26, "Recommendations of the International Commission on Radiological Protection", ICRP, 1977.
 - 12) Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix F", US NRC, 1977.
 - 13) Federal Guidance Report No.11, EPA-520-1-88-020, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", US EPA, 1988.
 - 14) ICRP Publication 68, "Dose Coefficients for Intakes of Radionuclides by Workers", ICRP, 1994.
 - 15) ICRP Publication 71, "Age-dependent Doses to Members of the Public from Intake of Radionuclides : Part 4 Inhalation Dose Coefficients", ICRP, 1995.
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 - 18) 2000-08 , " , , , 2000.
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 - 20) 98-12 , " , , 1998.
 - 21) 2001-02 , " , , 2001.
 - 22) KNGR(III), N-001-END461-001, "Technical Report : New Source Term Study Report", Rev.A, KOPEC, 10/30/2000.
 - 23) KNGR(III), Memo from KOPEC/NSSS to KOPEC/AE, NND/ES-00064M, " 3 Offsite , 11/07/2000.
 - 24) KNGR(III), Memo from KNFC to KOPEC/AE, NFD/ES-00087M, " 3 Dose Analysis , 11/02/2000.
 - 25) "STARDOSE User Manual", Rev.0, Polestar Applied Technology, Inc., 1998.