

Source Terms and Radiological Consequence Analyses

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Source Terms and Radiological Consequence Analyses

- DG-1389 contains significant changes to BWR release fractions and timing
 - Doubling halogen releases can have wide-ranging impacts
 - Charcoal/HEPA loadings and heat loads, EQ
 - NEI Comment #4 suggests incorporating results from supporting analyses performed by staff
 - Many BWR plants may not be able to adopt Rev. 1 without significant licensing basis changes or plant modifications
 - Example 1: demonstrates when applying the proposed release fractions and timing, plant will not meet the CR dose criteria for current BU and enrichment conditions
 - Example 2: demonstrates applying credit for the condenser using the proposed methods in conjunction with the proposed release fractions and timing, plant will meet the CR dose criteria for current BU and enrichment conditions
 - Example 3: demonstrates applying the proposed release fractions and timing to a plant already using credit for the condenser will not meet the CR dose criteria for current BU and enrichment conditions

Changes for BWR MHA-LOCA Scenario



BWR Release Fractions

Nuclide Group	Reg Guide 1.183, Rev. 0			Draft Guide DG-1389		
	Gap	In-Vessel	Total	Gap	In-Vessel	Total
Noble Gases	5.00E-02	9.50E-01	1.00E+00	8.00E-03	9.60E-01	9.68E-01
Halogens	5.00E-02	2.50E-01	3.00E-01	3.00E-03	5.40E-01	5.43E-01
Alkali Metals	5.00E-02	2.00E-01	2.50E-01	3.00E-03	1.40E-01	1.43E-01
Tellurium Metals	0.00E+00	5.00E-02	5.00E-02	3.00E-03	3.90E-01	3.93E-01
Barium, Strontium	0.00E+00	2.00E-02	2.00E-02	0.00E+00	5.00E-03	5.00E-03
Noble Metals	0.00E+00	2.50E-03	2.50E-03	0.00E+00	2.70E-03	2.70E-03
Cerium	0.00E+00	5.00E-04	5.00E-04	0.00E+00	1.60E-07	1.60E-07
Lanthanides	0.00E+00	2.00E-04	2.00E-04	0.00E+00	2.00E-07	2.00E-07
Molybdenum	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-02	3.00E-02

Nuclide Groups

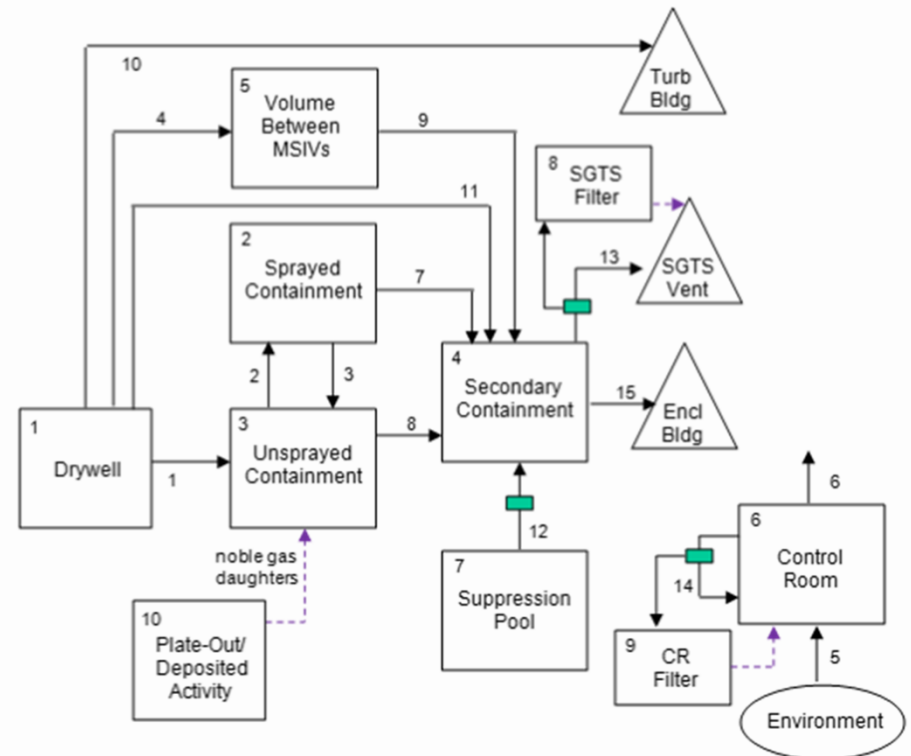
Nuclide Group	Table 5 of Reg Guide 1.183 Rev. 0	Table 14 of SAND 2011-0158
Noble Gases	Xe, Kr	Xe, Kr
Halogens	I, Br	I, Br
Alkali Metals	Cs, Rb	Cs, Rb
Tellurium Metals	Te, Sb, Se	Te, Sb, Se
Barium, Strontium	Ba, Sr	Ba, Sr
Noble Metals	Ru, Rh, Pd, Mo, Tc, Co	Ru, Rh, Pd, Co
Ceriums	Ce, Pu, Np	Ce, Pu, Np, Zr
Lanthanides	La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am	La, Nd, Eu, Pm, Pr, Sm, Y, Cm, Am
Molybdenum		Mo, Tc, Nb

Release Timing

Release Phase	Table 4 of Reg Guide 1.183 Rev. 0		Table 5 of Draft Guide DG-1389	
	Onset	Duration	Onset	Duration
Gap	2 min	30 min	2 min	0.16 hrs
Early In-Vessel	30 min	1.5 hrs	0.16 hrs	8.0 hrs

Example 1: BWR-6, Mark-III Containment

- BWR/6, Mark-III Containment
- Standard Leakage Paths
 - MSIV leakage
 - Containment leakage
 - ESF liquid leakage into Secondary CMT
- Main Steam Credit
 - No credit for MSL deposition past the outboard MSIV
 - Credit for MSIV Leakage Control System initiation at 20 minutes
 - ◆ 99% SGTS filters, ~1 hour holdup

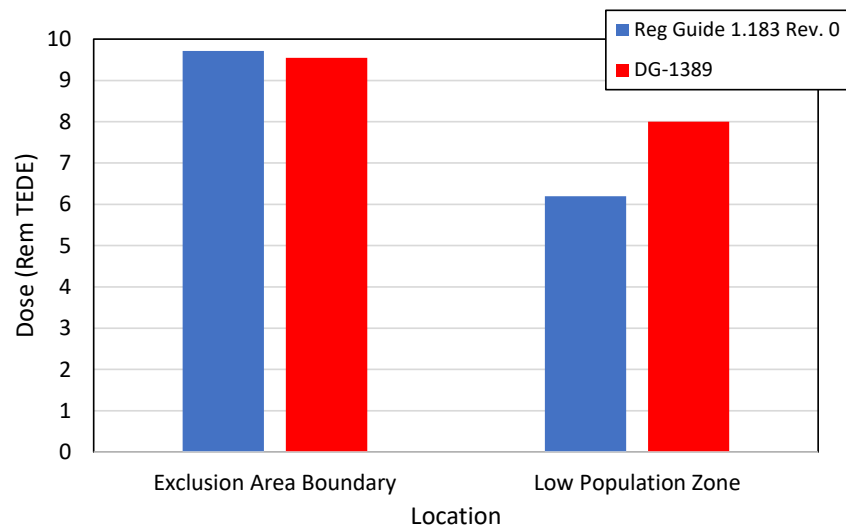


Results from Proposed Reg Guide Changes

Offsite Doses

Dose Location	Reg Guide 1.183 Rev. 0	DG-1389
Exclusion Area Boundary	9.71 (2-4 hrs)	9.55 (7.9-9.9 hrs)
Low Population Zone	6.20	8.00
Control Room	4.11	5.83

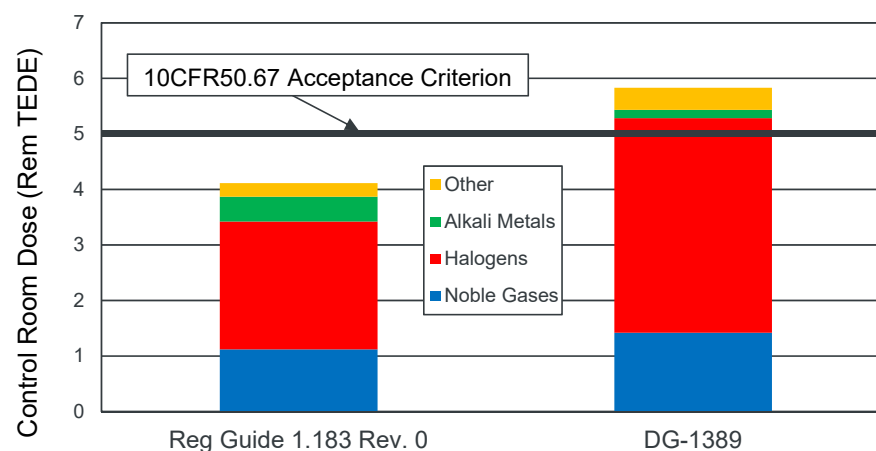
Offsite Doses



Control Room Doses

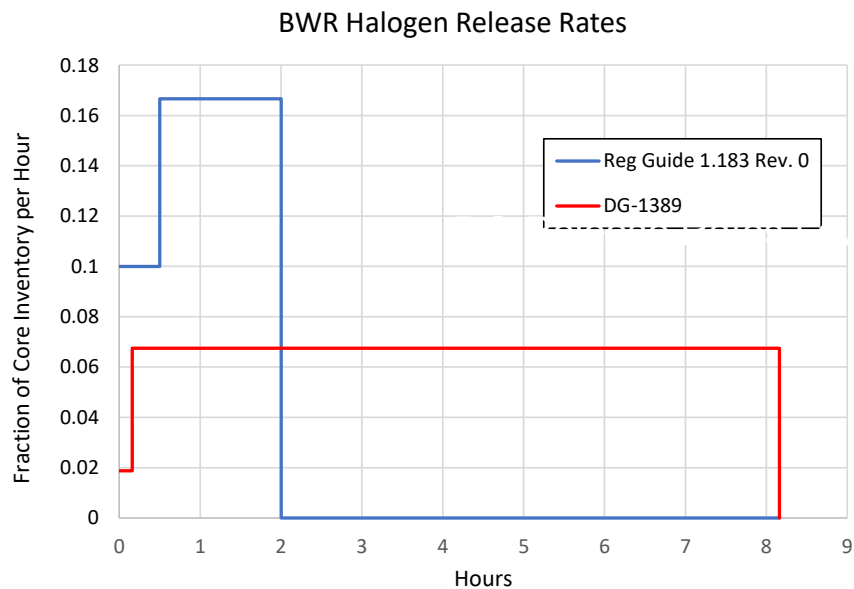
Release Group	Reg Guide 1.183 Rev. 0	DG-1389
Noble Gases	1.12E+00	1.42E+00
Halogens	2.30E+00	3.86E+00
Alkali Metals	4.46E-01	1.48E-01
Other	2.46E-01	3.97E-01
Total	4.11E+00	5.83E+00

Control Room Dose

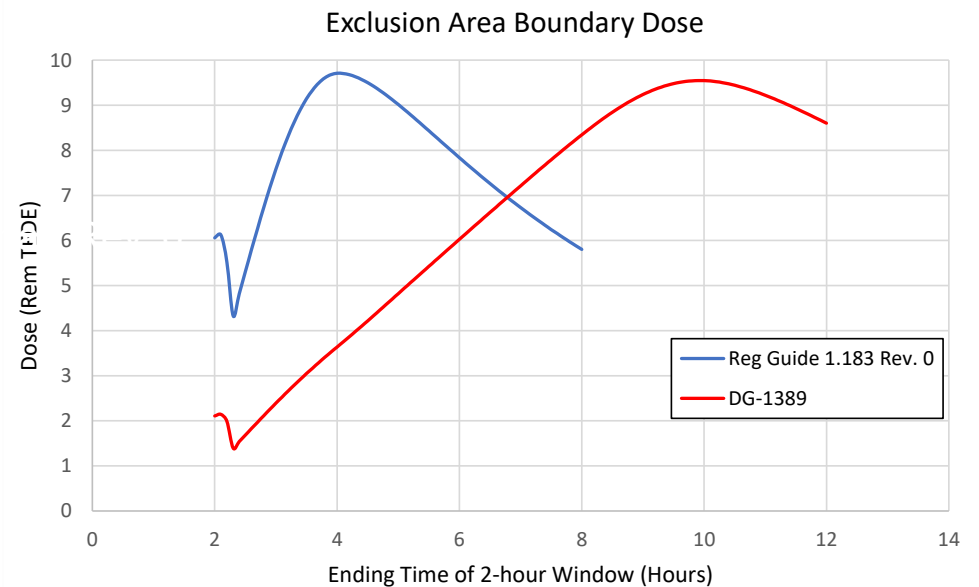


Results from Proposed Reg Guide Changes

DG Release Rates Lower than Rev. 0



Extended-Release Duration leads to later EAB peak



Example 2: BWR-4, Mark-I Containment

- Main Steam Credit
 - 300 scfh total / 150 max individual line
 - Credit for Aerosol Deposition between intact MSIVs, MSIV to TSV, and TSV through Condenser using RG 1.183 Table A-1
 - Addition of Condenser
- Removal Mechanisms
 - Containment Elemental Iodine Plateout from Wetted Surface
 - Containment Aerosol Deposition (Powers 10% model)
 - No Suppression Pool Scrubbing
- Leakage Paths
 - MSIV leakage
 - Containment leakage
 - ESF Leakage

Example 2: BWR-4, Mark-I Containment

■ MSIV Aerosol Changes

Leak Path	Removal Coefficient [1/hr]		Leak Rate [scfh]	Volume [ft ³]	Effective Filter Efficiency [%]		RG 1.183 Rev. 0 [AEB 98-03]
	0-10 hr	10+hr			0-10 hr	10+hr	0-96 hr
Intact inner MSIV to intact outer MSIV	1.8	1	150	66.05	44.2%	30.6%	93.8%
Intact outer MSIV to TSVs	1	0.7	150	869.96	85.3%	80.2%	97.5%
Failed line outer MSIV to TSVs	1	0.7	150	869.96	85.3%	80.2%	97.5%
TSV to Condenser	0.015	0.012	300	300000	93.8%	92.3%	0%

■ Elemental Deposition – no change to MSL methods, no credit in condenser

Results from Proposed Reg Guide Changes

- No Condenser
 - Strict reduction in deposition
 - Unviable increase in CR dose

	Control Room	LPZ	EAB
RG 1.183 R0	4.44E+00	2.59E+00	5.42E+00
RG 1.183 R1	5.16E+01	1.99E+01	1.11E+01
Delta	1061%	667%	105%

Results from Proposed Reg Guide Changes

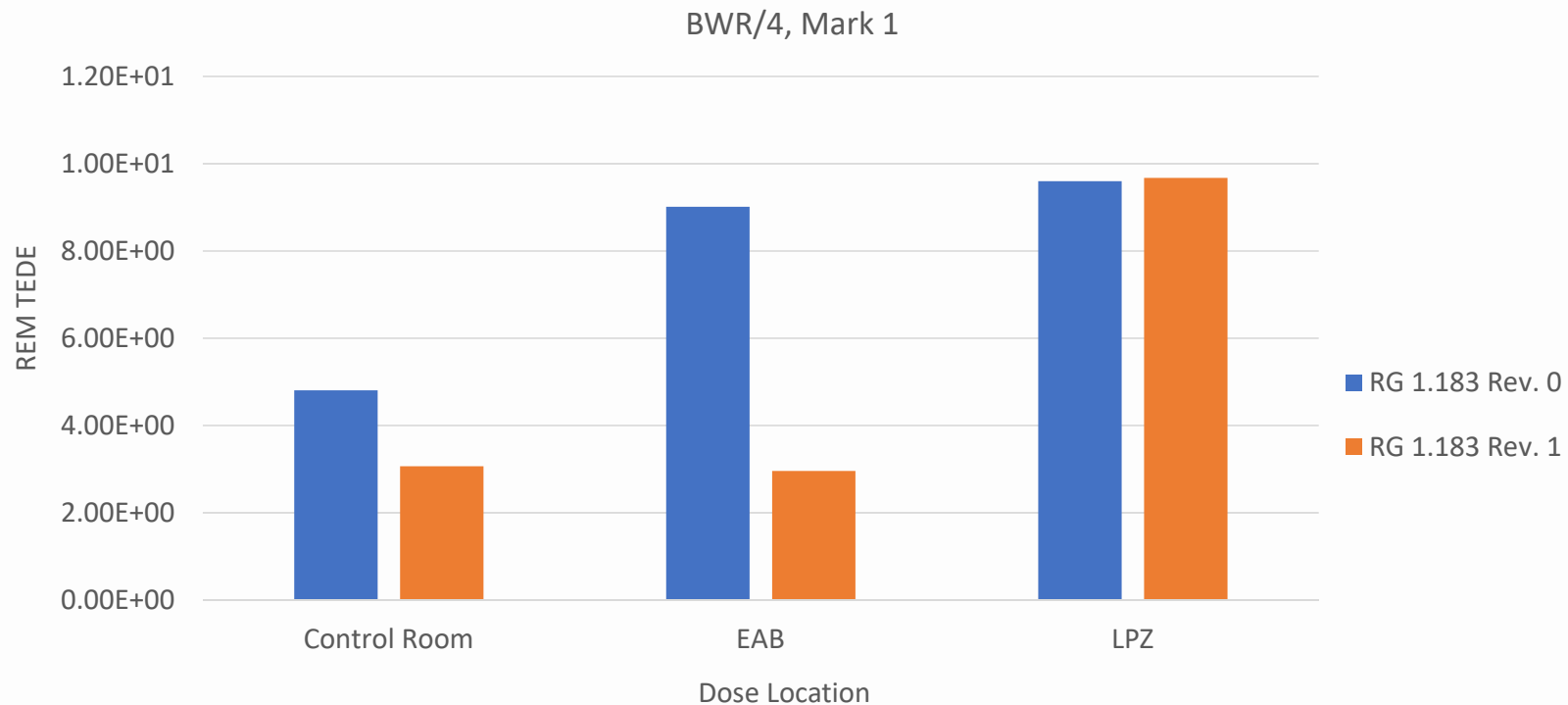
- Results with condenser compartment added to Rev. 1 case

RG 1.183 Rev. 1			
	Control Room	EAB	LPZ
Containment Leakage	9.80E-02	1.42E+00	3.25E+00
ESF Leakage	3.05E-02	1.09E+00	5.95E+00
MSIV Leakage	2.89E+00	4.51E-01	4.76E-01
Containment Shine	3.17E-02	0.00E+00	0.00E+00
External Cloud	1.30E-02	0.00E+00	0.00E+00
CR Filter Shine	3.15E-03	0.00E+00	0.00E+00
TOTAL	3.07E+00	2.96E+00	9.68E+00

RG 1.183 Rev. 0			
	Control Room	EAB	LPZ
Containment Leakage	2.61E-01	2.92E+00	3.14E+00
ESF Leakage	5.84E-02	6.74E-01	3.87E+00
MSIV Leakage	4.44E+00	5.42E+00	2.59E+00
Containment Shine	3.17E-02	0.00E+00	0.00E+00
External Cloud	1.30E-02	0.00E+00	0.00E+00
CR Filter Shine	3.15E-03	0.00E+00	0.00E+00
TOTAL	4.81E+00	9.01E+00	9.60E+00

Results from Proposed Reg Guide Changes

- Results with condenser compartment added to Rev. 1 case



Example 3: BWR-5, Mark-II Containment

- 400 scfh total / 200 max individual line
- Currently credits condenser for aerosol & elemental I removal
- Current model is AEB 98-03 for deposition
- Table A-1 applied directly to compartments

**Compartment 2: (Node 1) Inboard MSL A Volume
Removal Coefficients (1/hour)**

	Time (h)	Aerosol	Elemental I
1	0	1.800E+00	0.000E+00
2	10.0000	1.000E+00	0.000E+00
3	720.0000	0.000E+00	0.000E+00

**Compartment 3: (Nodes 2_3) Outboard MSL A Volume
Removal Coefficients (1/hour)**

	Time (h)	Aerosol	Elemental I
1	0	1.000E+00	0.000E+00
2	10.0000	7.000E-01	0.000E+00
3	720.0000	0.000E+00	0.000E+00

**Compartment 4: Condenser
Removal Coefficients (1/hour)**

	Time (h)	Aerosol	Elemental I
1	0	1.500E-02	0.000E+00
2	10.0000	1.200E-02	0.000E+00
3	720.0000	0.000E+00	0.000E+00

Results from Proposed Reg Guide Changes

- Control Room resulting dose very high through failed line (MSL B)

	Control Room	LPZ	EAB
MSIV A	3.20E+00	2.54E-02	6.18E-02
MSIV B	1.61E+01	5.61E-02	2.99E-01
ECCS	2.47E-02	1.73E-02	3.09E-02
Containment Leakage	5.12E-01	9.89E-02	6.96E-01
Total	1.98E+01	1.98E-01	1.09E+00

- Overall decrease in Iodine removal without compensation.

Discussion

- State-of-the-Art Reactor Consequence Analyses (SOARCA) project results¹ include the suppression pool in their models and indicate that all modeled accident scenarios, progress more slowly and release smaller amounts of radioactive material than calculated in earlier studies
 - PWRs saw these expected impacts while BWRs did not
- Reg Guide should not unduly penalize BWRs
- Potential Resolutions
 - Update BWR release fractions with more applicable accident scenario selection
 - Consider suppression pool scrubbing credit in BWR release fractions
 - NUREG/CR-6153 provides one scrubbing model through SRVs
 - A small DF of just 2 would be adequate to resolve the issue

¹ ML20304A339 – NRC Brochure- State-of-the-Art Reactor Consequence Analyses: Using decades of research and experience to model accident progression, mitigation, emergency response, and health effects

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- Additional concerns with addressing TFGR - no guidance is provided in the DG to address TFGR due to high burnup pellet fragmentation in non-LOCA accidents that predict fuel failure aside from reactivity insertion accidents that are addressed in RG 1.236
 - High burnup-related TFGR guidance for non-LOCA DBAs should be provided
 - For non-LOCA DBA with fuel overheating, guidance should identify the specific non-LOCA DBAs that are impacted and include applicable TFGR guidance in the relevant Appendices