Offsite Radiological Dose Assessment of Postulated Line Break for Dresden and Quad Cities

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Abstract

Radiological dose assessments were made to assess the consequences of a postulated RWCU line break. The thyroid doses calculated were less than 10CFR100 limits.

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1. Introduction

The purpose of this calculation is to determine the offsite (Exclusion Area Boundary) thyroid dose due to a postulated line break in the reactor water cleanup (RWCU) system. The calculated doses will be compared to the acceptance criteria of 10CFR100 and, for comparison purposes only, those included in the UFSAR for the instrument line break and main steam line break accident (MSLBA).

2. Methodology

2.1 Model

The postulated line break in the reactor water cleanup system releases a mass of reactor water (at reactor pressure) to the reactor building. Upon depressurization, some of the water flashes to steam carrying with it some of the radioiodine released in the reactor coolant. The resulting pressure in the reactor building is assumed to be such that the reactor building's containment function (and standby gas treatment system) does not function to mitigate the consequences of this scenario. The steam and radioiodine are released from the upper levels of the reactor building to the environment in a manner similar to that assumed for a MSLBA. No credit is taken for iodine plateout within the reactor building for this assessment.

The thyroid dose is calculated from the product of the following four terms:

1. the I-131 release expressed as curies (Ci) of I-131 dose equivalent (I-131 DE)
2. the relative atmospheric dispersion factor X/Q [s/m**3]
3. the breathing rate [m**3/s], and
4. the inhalation dose conversion factor (DCF) for I-131 [rem/Ci inhaled]

For convenience, this calculation has been set up on an EXCEL spreadsheet.

2.2 Assumptions

Guidance for the radiological assessment of line breaks similar to the present RWCU assessment may be found in USNRC Regulatory Guide 1.5 (Steam Line Break) [Ref. 1] and USNRC Standard Review Plan 15.6.2 (Small Line Breaks Outside of Containment) [Ref. 2]. Selected portions of each of these have been utilized as neither addresses the break currently under review.

The data used in the assessment are given below. Supporting commentary is provided when deemed to be of importance.

Mass of coolant released through the break ..... 815,000 pounds [Ref. 3]

Coolant I-131 dose equivalent concentration ..... 0.2 uCi/g [Ref. 4]

This upgraded Technical Specification (3.6.J) states that "The specific activity of the reactor coolant shall be limited to [less than or equal to] 0.2 uCi/gram DOSE EQUIVALENT I-131."

Fraction of steam [and I-131] flashed to steam 0.375

(The instrument line break assessment standard review plan (Ref. 2) states "The fraction of the iodine assumed to become airborne and available for release to the atmosphere, without credit for plateout, is equal to the fraction of the coolant flashing into steam in the depressurization process. The flash fraction is determined by assuming the discharge to be a constant enthalpy process.")

This value is determined as follows:

At 1020 psia, the enthalpy (from steam tables) of liquid is h = 544.3 Btu/lb

At 14.7 psia, the enthalpies of the liquid (hf), steam (hg) and heat of vaporization (hfg) are:

hf = 180.07 Btu/lb
hfg = 970.3 Btu/lb
hg = 1150.4 Btu/lb

From an energy balance (constant enthalpy process), the fraction F of liquid at 1020 psia flashing to steam when depressurized to 14.7 psia is calculated as follows:

The enthalpy of one pound of liquid at 1020 psia is = h
The enthalpy of the resulting depressurized steam and liquid at 14.7 psia is [F x hg + (1-F) x hf], where F is the fraction of the unit mass which flashes to steam.

Equating the enthalpy of the unit liquid mass at 1020 psia to the combined enthalpy of water and steam at 14.7 psia results in the equation:

h = F x hg + (1-F) x hf

F= (h-hf)/(hg-hf) = (h-hf)/hfg

F = (544.3-180.07)/970.3 = 0.375

X/Q values are taken from Reg Guide 1.5, Figure 1 [Ref. 1]:
Dresden (EAB at 800 m) X/Q = 4.2E-4 s/m**3
Quad Cities (EAB at 385 m) X/Q = 8.0E-4 s/m**3
(These values of X/Q are the same as used in assessing the MSLBA, namely a release [thru blowout panels] at an elevation of 30 m followed by atmospheric fumigation conditions.)

Dose conversion factor..... 1.08E+6 rem-thyroid per Curie inhaled

(This parameter is derived from data included in ICRP-30 [Ref. 5] and also published in Federal Guidance Report No. 11 [Ref. 6]. This data is also incorporated in the revision to 10CFR20 [Ref. 7]

Breathing rate..... 3.47E-4 cubic meters/second [Ref. 1; Reg Guide 1.5]

3. Calculations

Calculations for the offsite thyroid dose due to the reactor water cleanup line break are presented in the Appendix A attachment.

4. Results

The resulting thyroid doses at the EAB are:

Dresden 4.4 rem
QuadCities 8.3 rem

These are a small fraction of the 10CFR100 thyroid dose limit of 300 rem.

Comparison with other UFSAR Doses:

For comparison, the present assessments for the RWCU line break may be compared to the following UFSAR assessments for line breaks outside of containment. (Note that the doses shown here are the maximum values of many assessments reported in the UFSAR over the course of the plants' licensing history.)

Dresden --
Instrument Line Break (UFSAR Table 15.6-2) 128 Rem at the EAB
Main Steam Line Break (UFSAR Section 15.6.4.5, SEP assessment) 80 Rem at the EAB

Quad Cities --

Instrument Line Break (UFSAR Section 15.6.2.4) 110 Rem at the EAB
Main Steam Line Break (UFSAR Section 15.6.4.5) 22 Rem at the EAB

Note that the doses calculated for the RWCU system line break are less than those maximum values reported in the UFSAR for the instrument line break and the MSLB accidents.

5. Conclusions

The calculated thyroid dose at the Exclusion Area Boundary due to a postulated break in an RWCU system line is less than 10CFR100 limits.

6. References

1) USNRC, Assumptions Used For Evaluating the Potential Radiological Consequences of a Steam Line Break Accident for Boiling Water Reactors, Regulatory Guide 1.5 [Safety Guide 5], 3/10/71.

2) USNRC, Radiological Consequences of the Failure of Small Lines Carrying Primary Coolant Outside Containment, Standard Review Plan 15.6.2 [NUREG-0800], Rev. 2, July 1981.

3) ComEd, Nuclear Fuels Services calculation BSA-M-96-09, Maximum Mass Release for a RWCU Line Break at Dresden or Quad Cities.

4) Upgraded Technical Specifications, Dresden and Quad Cities stations, Section 3.6.J.

5) ICRP Publication 30 and Supplements, Limits for Intakes of Radionuclides by Workers (adopted July 1978), Pergamon Press Oxford, 1979.

6) FGR-11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, K. F. Eckerman et al., USEPA Federal Guidance Report No. 11, 1988.

7) 10CFR20, Standards for Protection Against Radiation, Final Rule, Federal Register, Vol. 56, pg. 23390-23474, May 21, 1991.

Appendix A - EXCEL Spreadsheet Calculations

file d&qrwcu.xls Calculation of Offsite Thyroid Dose Due to Line Break in Reactor Water Cleanup System

GPL 8/26/96		RWCU Break assessment				
file GPL_proj\RWCU.xls						
Reference section:						
Iodine concentration, I-131 dose equivalent, 0.2 uCi/g						
Source: Dresden and Quad Cities TSUP section 3.6.J						
X/Q [sec/m**3]				I-131 Dose Conversion Factor,		
from Reg Guide 1.5, Figure 1				rem[thryroid] per Ci inhaled		
at 385 m	8.00E-04			FGR-11	2.92E-07	Sv/Bq
at 800 m	4.20E-04			=	1080.4	mrem/uCi
				=	1.08E+06	rem/Ci
				breathing rate, 10 m**3 per 8 hours		
Step 1. Calculate I-131 DE release						
water mass released, pounds	8.15E+05					
water mass released, grams	3.70E+08					
I-131 DE, uCi/g	0.2	[TSUP limit]				
Curies I-131 in fluid	74.002					
Flashing fraction	0.375	[reduction allowed by SRP 15.6.2.III.3.d]				
Curies I-131 airborne	27.751	[released without further reduction]				
Step 2. Calculate thyroid dose						
*** Dose = release * X/Q * breathing rate * DCF						
Thyroid DCF,rem/curie	1.08E+06	[ICRP-30]				
breathing rate, m**3/sec	3.47E-04	[RegGuide 1.5]				
Step 2a. Calculate thyroid dose -- Dresden						
X/Q at EAB [800m]	4.20E-04					
Thyroid dose, rem	4.37					
Step 2b. Calculate thyroid dose -- Quad Cities						
X/Q at EAB [385 m]	8.00E-04					
Thyroid dose, rem	8.33					

Appendix B - EXCEL Spreadsheet with Formulas

file d&qrwcua.xls Calculation of Offsite Thyroid Dose Due to Line Break in Reactor Water Cleanup System

	A	B	C
1	GPL 8/26/96		RWCU Break assessment
2	file GPL_proj\RWCU.xls		
3			
4	Reference section:		
5	Iodine concentration, I-131 dose equivalent, 0.2 uCi/g		
6	Source: Dresden and Quad Cities TSUP section 3.6.J		
7			
8	X/Q [sec/m**3]		
9	from Reg Guide 1.5, Figure 1		
10	at 385 m	0.0008	
11	at 800 m	0.00042	
12			
13			
14			
15	Step 1. Calculate I-131 DE release		
16	water mass released, pounds		815000
17	water mass released, grams		=C16*454
18	I-131 DE, uCi/g		0.2
19	Curies I-131 in fluid		=C18*C17/1000000
20	Flashing fraction		0.375
21	Curies I-131 airborne		=C19*C20
22			
23	Step 2. Calculate thyroid dose		
24	*** Dose = release * X/Q * breathing rate * DCF		
25	Thyroid DCF,rem/curie		=F12
26	breathing rate, m**3/sec		=10/8/3600
27			
28	Step 2a. Calculate thyroid dose -- Dresden		
29	X/Q at EAB [800m]		=B11
30	Thyroid dose, rem		=C21*C25*C26*C29
31			
32	Step 2b. Calculate thyroid dose -- Quad Cities		
33	X/Q at EAB [385 m]		=B10
34	Thyroid dose, rem		=C21*C25*C26*C33

file d&qrwcua.xls (continued)

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18	[TSUP limit]
19	
20	[reduction allowed by SRP 15.6.2.III.3.d]
21	[released without further reduction]
22	
23	
24	
25	[ICRP-30]
26	[RegGuide 1.5]
27	
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file d&qrwcua.xls (continued)

	E		F	G
1				
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7				
8	I-131 Dose Conversion Factor,			
9	rem[thryroid] per Ci inhaled			
10	FGR-11		0.000000292	Sv/Bq
11		=	=F10*3700000000	mrem/uCi
12		=	=F11*1000	rem/Ci
13				
14	breathing rate, 10 m**3 per 8 hours			
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ATTACHMENT B

REACTOR WATER CLEANUP LINE BREAK
ENVIROMENTAL QUALIFICATION OF AFFECTED EQUIPMENT

Attachment B

Dresden Units 2 and 3
Quad Cities Units 1 and 2
Reactor Water Cleanup Line Break
Environmental Qualification of Affected Equipment

At Dresden and Quad Cities Stations, the environmental qualification of equipment under 10 CFR 50.49 is established to achieve the safe shutdown condition, which for Dresden and Quad Cities has been defined as hot shutdown. Equipment environmental qualification is performed for environmental parameters that exceed 120 ^{o}F, 5 x 10E4 rads TID and 100% RH, condensing for any postulated design basis event, in accordance with the requirements of IEB 79-01b.

Originally, for the Dresden and Quad Cities Stations, the postulated Reactor Water Cleanup (RWCU) linebreaks were determined and evaluated in Special Reports Number 37 and 12, "Analysis of Effects of Pipe Breaks Outside Primary Containment", respectively. Subsequent analyses established a blow down period of 40 seconds at Dresden and 50 seconds at Quad Cities, before break isolation occurs, concurrent with postulating a loss of offsite power (LOOP).

With the new postulated extension of the blow down period of up to 10 minutes before beginning system isolation, and a LOOP is not postulated, the environmental parameters in affected EQ Zones change. These changes resulted in the need to reevaluate the environmental qualification of the equipment necessary to mitigate the effects of the RWCU linebreak. The results of this evaluation are summarized below:

Dresden:

For the extended postulated RWCU linebreak period of 10 minutes, plus the 40 second isolation time, the preliminary evaluations have determined that the environmental parameters increase to the following:

EQ Zone #	Peak Temperature	Relative Humidity
2(Torus)	110 ^{o}F	100%
10 to 18(Ground Floor)	150 ^{o}F	100%
22 to 27(Mezzanine)	212 ^{o}F	100%
28(RWCU HX Room)	226 ^{o}F	100%
34 to 40(Main Floor)	212 ^{o}F	100%

The 4KVAC essential switchgear located on elevation 545' and the 480VAC MCCs located on elevation 517' are postulated to be affected by the break. Due to the exposure, they are postulated to not be available. However the DC system would be available to power the outboard isolation valve, to isolate the break, since the DC MCCs are located on elevation 570' in EQ Zone 36 and are environmentally qualified for the new parameters . The isolation (closure of the valve) would be accomplished manually from the control room.

The equipment affected that is needed to achieve hot shutdown has been shown to be qualified to the above parameters and includes the following:

1) For break detection:

   a) Ten Conax Model 7A11- 10002-01 RTD Temperature Detectors located in Zones 22 and 28.

2) For break isolation:
   a) Limitorque Model SMB 1-60 Actuator in Zone 22
   b) Cutler-Hammer 250 VDC Motor Control Center in Zone 36

3) For achieving hot shutdown(safe shutdown):

   a) Four Barksdale Model BT-M12SS-GE Pressure Switches in Zones 24 and 27
   b) One Limitorque Model SMB-000 Actuator in Zone 10
   c) One Limitorque Model SMB-1-60 Actuator in Zone 22
   d) Two ASCo Model HVA90-405-2A Solenoid Valves in Zones 10, 14 and 16
   e) Four ITT Barton Model 288/288A Pressure Switches in Zone 10
   f) Two Limitorque Model ALW Local Control Panels in Zone 22
   g) One Cutler-Hammer 250 VDC Motor Control Center in Zone 36

After isolating the RWCU system, the isolation condenser (ISCO) is initiated by manually opening valve 1301-3 from the control room. When ISCO make up is required, supply is provided by manually starting the ISCO pump(s). Further, back up sources of water for the shell side make up are provided from the Fire Protection pumps and the Service Water pumps. The ISCO is used to bring the Unit to the hot shutdown condition.

The CRD system can provide additional make up water to reactor if required.

Quad Cities:

For the extended postulated RWCU linebreak period of 10 minutes, plus the 50 second isolation time, the preliminary evaluations have determined that the environmental parameters increases to the following:

EQ Zone #	Peak Temperature	Relative Humidity
2(Torus)	110 F	100%
11 to 17 (Ground Floor)	150 F	100%
22, 24 to 27(Mezzanine)	212 F	100%
28(RWCU HX Room)	226 F	100%
29 to 35a (Main Floor)	212 F	100%
37& 38 (Refuel Floor)	212 F	100%

At Quad Cities Station, for HELB's outside containment, other than for a Main Steam Line Break (MSLB), the Main Steam Isolation Valves are open and the condenser is available for pressure and temperature control. High Pressure Coolant Injection is available for water inventory control.

The 4KVAC essential switchgear for Quad Cities Station is located in the Turbine Building and therefore, is not affected by the break. The 480VAC and 250VDC MCCs located on elevation 595' and 623' are postulated to be affected by the break, and have been evaluated to confirm their capability to perform their safe shutdown function while being exposed to a HELB.

The DC system would also be available to power the outboard isolation valve, to isolate the break, since the DC MCCs environmental qualification envelopes the new environmental parameters. The isolation (closure of the valve) would be accomplished manually from control room.

The equipment affected that is needed to achieve hot shutdown has been shown to be qualified to the above parameters and includes the following:

1) For break detection:

   a) Six Conax Model 7A11- 10002-01 RTD Temperature Detectors located in Zone 22.

2) For break isolation:

   a) One Limitorque Model SMB 2 Actuator in Zone 22
   b) One Cutler-Hammer 250 VDC Motor Control Center in Zone 27

3) For achieving and maintaining hot shutdown:

   a) HPCI components that are located in EQ Zones, 5, 7, 10, and 27
   b) One Cutler-Hammer 250 VDC Motor Control Center in Zone 27
   c) Six Rosemount Model 1153 Pressure Transmitters in Zone 16

After isolating the RWCU system, a normal, controlled shutdown would be performed. The condenser and HPCI is used to bring the Unit to the hot shutdown condition and maintain the unit in this safe shutdown condition.

CRD system can provide additional make up water to reactor if required

Overall, the environmental qualification basis of the equipment at Dresden and Quad Cities needed to achieve hot shutdown has been reviewed and the current environmental qualification envelopes the new environmental qualification parameters. This equipment will continue to perform its intended function, to indicate, isolate the break and bring the affected units to safe shutdown.